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CANADA
DEPARTMENT OF MINES
MINES BRANCH
HON. W. TEMPLEMAN, MINISTER; A. P. LOW, LL.D., DEPUTY MINISTER;
EUGENE HAANEL, PH.D., DIRECTOR.

AN
INVESTIGATION
OF THE
COALS OF CANADA
WITH REFERENCE TO THEIR ECONOMIC QUALITIES:
AS CONDUCTED AT McGILL UNIVERSITY, MONTREAL, UNDER THE AUTHORITY OF THE DOMINION GOVERNMENT.

IN SIX VOLUMES

BY
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THE
COALS OF CANADA:
AN ECONOMIC INVESTIGATION
VOL II

PART VII
BOILER TESTS
BY
R. J. DURLEY

PART VIII
GAS PRODUCER TESTS
BY
R. J. DURLEY

PART IX
WORK OF THE CHEMICAL LABORATORY
BY
EDGAR STANSFIELD

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TABLE OF CONTENTS.

VOLUME II

PART VII.

PAGE

Boiler Tests, by R. J. Durley. 3
  - Types of boilers, and their efficiency 3
  - Coal, and its suitability for steam generating purposes 5
  - Boiler furnaces and their adaptability for various coals 7
  - Boiler trials, and their use in testing coals. 9
  - Equipment: brief description of plant and apparatus used for boiler trials. 15
  - Method of conducting tests and making measurements: log and calculations for one trial 18
    - Duties of staff, method of handling fuel and starting and stopping trials. 18
    - Measurement of water. Dryness of steam. Flue gas analysis. 19
    - Results of boiler trial No. 58. 21
      - Log of trial with observation sheets. 21
      - Summary of observations 23
      - Summary of results. 26
      - Details of calculations involved in the determination of the resultant figures given in the summaries of observations and results. 27
  - Remarks on boiler trials and their results. 32
    - Value of coal. 32
    - Composition of coals. 32
    - Condition of coals when tested. 33
    - General tabular statement of results of whole series of trials 33
    - Relative merit of the coals 34
    - Treatment and behaviour of coal in fire. 39
  - Remarks on coals as arranged geographically by coal fields. 40
    - Sydney coal field, Cape Breton co., N.S. 40
    - Inverness coal field, Inverness co., N.S. 41
    - Pictou coal field, Pictou co., N.S. 42
    - Springhill coal field, Cumberland co., N.S. 43
    - Joggins-Chignecto coal field, Cumberland co., N.S. 44
    - Grand Lake coal field, N.B. 44
    - Souris, Edmonton, and Belly River coal fields, Saskatchewan and Alberta. 45
    - Frank-Blairmore coal field, Alberta. 46
    - Crowsnest coal field, B.C. 47
    - Cascade coal field, Alberta. 48
    - Nicola Valley coal field, B.C. 49
    - Nanaimo-Comox, and Alert Bay coal fields, B.C. 50

PART VIII.

GAS PRODUCER TESTS, by R. J. Durley.

Gas producers and their method of working. 56
- Gas producers for non-bituminous fuels. . 56
- Gas producers for bituminous fuels. . 61

Gas producer tests, and methods of testing coals in gas producers [illegible]

Equipment of experimental plant for gas producer tests of Canadian coals. . 72
- General arrangement of plant and accessories. . 77

Methods of conducting tests, and making measurements: (with log and calculations for one trial). 79
- Method of handling fuel, and starting and stopping trials 81
- Temperatures, pressures, and other details of test 82
- Determination of rate of fuel consumption. 84
- Detailed results of producer trial No. 32. 85
  - Log of trial, with observation sheets. 85
  - Summary of observations 86
  - Summary of results. 89
  - Details of calculations involved in the determination of the resultant figures given in the summaries of observations and results. . 95

Remarks on gas producer trials and their results: value of coals for gas producer work . 102
- Treatment and condition of coals when tested 102
- General results. . 102
- Producer efficiency, as illustrated by proportion of combustible in coal, in refuse, and in producer contents. . 103
- Relative merit of the coals 107

Remarks on coals, as arranged geographically by coal fields 107
- Sydney coal field, Cape Breton, N.S. . . 107
- Inverness and Pictou coal fields, N.S. 108
- Springhill and Joggins coal fields, N.S., and Grand Lake coal field, N.B. 109
- Souris coal field, Sask., Edmonton and Belly River coal fields, Alta. 110
- Frank-Blairmore coal field, Alta. 112
- Crowsnest coal field, B.C. . 113
- Cascade coal field, Alta 115
- Nicola Valley, and the Nanaimo coal fields, B.C. . . 117

Heat expenditure with various coals. . 118

PART IX.

PAGE

WORK OF THE CHEMICAL LABORATORY by Edgar Stansfield

- Introduction 121
- Collection and treatment of samples 122
  - Coal samples 122
  - Ash samples 126
  - Coke samples 126
  - Gas samples 126
- Numbering of samples 127
- Records and calculations 129
- Air drying coal 130
- Analytical methods and derived results 131
  - General remarks 131
  - Moisture 133
  - Fixed carbon and volatile matter 134
  - Ash 136
  - Carbon and hydrogen 136
  - Sulphur 140
  - Nitrogen 143
  - Oxygen [illegible]
  - Calorific value of solid fuels 146
  - Calorific value of ash free coal 155
  - Calorific value calculated from analysis of coal 155
  - Fuel ratio 156
  - Carbon-hydrogen ratio 156
  - Gas analysis 157
    - Gas analysis with Orsat-Muncke apparatus 158
    - Gas analysis with Randall and Barnhart apparatus 158
    - Gas analysis with Bone and Wheeler gas analysis apparatus 161
  - Calorific value of gaseous fuels 165
  - Calorific value calculated from analysis of gas 168
  - Miscellaneous determinations 173
- Experiments on the fusibility of ashes 174
- Discussion of work 176

List of coals tested 181

- Sydney coal field, N.S 181
- Inverness coal field, N.S. 181
- Pictou coal field, N.S. 181
- Springhill coal field, N.S 182
- Joggins-Chignecto coal field, N.S. 182
- Grand Lake coal field, N.B. 182
- Souris coal field, Sask. 182
- Edmonton coal field, Alta. 182

PAGE
Belly River coal field, Alta. 182
Frank-Blairmore coal field, Alta. 183
Crowsnest coal field, B.C. 183
Cascade coal field, Alta. 183
Similkameen coal field, B.C. 183
Nicola Valley coal field, B.C. 184
Nanaimo-Comox coal field, B.C. 184
Alert Bay coal field, B.C. 184
Whitehorse coal field, Yukon Territory. 184
Summary record in tabular form of all chemical analyses, arranged by coal fields in geographical order. Following 184

LIST OF TABLES

PAGE

PART VII

Table I. Detailed record of coal fired. 22
" II. Trials of No. 2 Babcock and Wilcox boiler with No. 36 coal. Following 22
" III. Detailed record of gas analysis. 23
" IV. Summary record of boiler tests. Following 32
" V. Trials of Georges Creek coal on No. 2 Babcock and Wilcox boiler. 36
" VI. Coals in order of evaporation. 38
" VII. Remarks on combustion of Sydney coals. 40
" VIII. Evaporation with Sydney coals. 41
" IX. " " Inverness coals. 41
" X. Remarks on combustion of Pictou County coals. 42
" XI. Evaporation with Pictou County coals. 43
" XII. " " Springhill coals. 43
" XIII. " " Joggins-Chignecto coals. 44
" XIV. " " Grand Lake coal. 44
" XV. Remarks on combustion of lignites and lignitic coals. 45
" XVI. Evaporation with lignites and lignitic coals. 45
" XVII. Remarks on combustion of Frank-Blairmore coals. 46
" XVIII. Evaporation with Frank-Blairmore coals. 47
" XIX. Remarks on combustion of Crowsnest coals. 47
" XX. Evaporation with Crowsnest coals. 48
" XXI. Remarks on combustion of Cascade coals. 49
" XXII. Evaporation with Cascade coals. 49
" XXIII. Evaporation with Nicola Valley coals. 50
" XXIV. Remarks on combustion of Vancouver Island coals. 50
" XXV. Evaporation with Vancouver Island coals. 51

PAGE

PART VIII

Table XXVI. Composition of gases per cent by volume. 57
" XXVII. " anthracite and coke. 57
" XXVIII. " typical gases from bituminous coal 61
" XXIX. Observations of composition of gas by volume. . 91
" XXX. " " gas meter and B.H.P. 92
" XXXI. " " gas calorimeter and coal weighed 93
" XXXII. " " temperatures and pressures. . . . 94
" XXXIII. Summary record of gas producer tests. Following 102
" XXXIV. Proportion of combustible in coal, in refuse, and in producer contents. 105
" XXXV. Performance with Cape Breton coals. 108
" XXXVI. " " Inverness and Pictou coals. . . . 109
" XXXVII. " " Springhill, Joggins, and Grand Lake coals. 110
" XXXVIII. Performance with lignites and lignitic coals. 111
" XXXIX. " " Frank-Blairmore coals. 113
" XL. " " Crowsnest coals. 114
" XLI. " " Cascade coals. 116
" XLII. " " Nicola Valley and Nanaimo coal. 117
" XLIII. Heat value of coal charged per B.H.P. per hour . . . 118

PART IX

Table XLIV. Report of analysis of coal—Coal Testing Laboratory. 129
" XLV. Recorded temperature of water in calorimeter vessel. 148
" XLVI. Analysis of producer gas with Randall and Barnhart apparatus. 161
" XLVII. Analysis of producer gas with Bone and Wheeler apparatus. 165
" XLVIII. Ethylene: gross or higher calorific value in B.T.U per cub. ft., moist, at 60°F. and 30". 169
" Ethylene: net or lower calorific value in B.T.U. per cub. ft., moist, at 60°F. and 30". 169
" XLIX. Carbon monoxide: gross and net calorific value in B.T.U. per cub. ft., moist, at 60°F. and 30" . . . 169
" L. Methane: gross or higher calorific value in B.T.U. per cub. ft., moist, at 60°F. and 30". 170
Methane: net or lower calorific value in B.T.U. per cub. ft., moist, at 60° F. and 30". 171
" LI. Hydrogen: gross or higher calorific value in B.T.U. per cub. ft., moist, at 60° F. and 30". 171
Hydrogen: net or lower calorific value in B.T.U. per cub. ft., moist, at 60° F. and 30". 172
" LII. Comparative ash determinations. 179

Table LIII. Summary of approximate errors in coal analyses.. PAGE 180
" LIV. Summary record of analyses of coals: Sydney coal-field, Cape Breton co., N.S. ...... Following 184
" LV. Summary record of analyses of coals: Inverness coal field, Inverness co., N.S. " 184
" LVI. Summary record of analyses of coals: Pictou coal field, Pictou, co., N.S.... " 184
" LVII. Summary record of analyses of coals: Springhill coal field, Cumberland co., N.S.... .... " 184
" LVIII. Summary record of analyses of coals: Joggins-Chignecto coal field, Cumberland co., N.S.. .... " 184
" LIX. Summary record of analyses of coals: Grand Lake coal field, N.B. ...... " 184
" LX. Summary record of analyses of coals: Souris coal field, Sask. .... " 184
" LXI. Summary record of analyses of coals: Edmonton coal field, Alta......... " 184
" LXII. Summary record of analyses of coals: Belly River coal field, Alta. ..... " 184
" LXIII. Summary record of analyses of coals: Frank-Blairmore coal field, Alta..... " 184
" LXIV. Summary record of analyses of coals: Crowsnest coal field, Alta. .... " 184
" LXV. Summary record of analyses of coals: Cascade coal field, Alta. ... . " 184
" LXVI. Summary record of analyses of coals: Similkameen coal field, B.C. .... " 184
" LXVII. Summary record of analyses of coals: Nicola Valley coal field, B.C. ...... " 184
" LXVIII. Summary record of analyses of coals: Nanaimo-Comox coal field, Vancouver island, B.C. .... " 184
" LXIX. Summary record of analyses of coals: Alert Bay coal field, Vancouver island, B.C. ... . " 184
" LXX. Summary record of analyses of coals: Whitehorse coal field, Yukon Territory. .... " 184
" LXXI. Summary record of analyses of coals: Standard coal used for comparison. " 184

ILLUSTRATIONS

Photographs

PART VII

PAGE
Plate XLVI. Boiler room, experimental steam plant, Department of Mechanical Engineering, McGill University. 16

PART VIII

Plate XLVII. Diagram of Westinghouse double zone producer, vertical section. 64
" XLVIII. Down-draft producer (No. 4), Department of Mechanical Engineering, McGill University. 76
" XLIX. Boys' gas calorimeter as set up for producer tests, Department of Mechanical Engineering, McGill University. 78
" L. Interior of gas producer laboratory, looking west, Department of Mechanical Engineering, McGill University. 80
" LI. Interior of gas producer laboratory, looking east, Department of Mechanical Engineering, McGil University. 80

PART IX

Plate LII. Small ball mill for grinding samples, Department of Mining and Ore Dressing, McGill University 124
" LIII. Small ball mill, opened for cleansing, Department of Mining and Ore Dressing, McGill University. 124
" LIV. Drying apparatus—Chemical Laboratory, Department of Mining and Ore Dressing, McGill University. 132
" LV. Kjeldahl nitrogen distillation apparatus, Chemical Laboratory, Department of Mining and Ore Dressing, McGill University. 144
" LVI. Koehler bomb calorimeter, general view, Department of Mining and Ore Dressing, McGill University. 148
" LVII. Randall and Barnhart gas analysing apparatus, general view, Department of Mining and Ore Dressing, McGill University. 158
" LVIII. Bone and Wheeler gas analysing apparatus, general view, Department of Mining and Ore Dressing, McGill University. 162
" LIX. Bone and Wheeler gas analysing apparatus, details, Department of Mining and Ore Dressing, McGill University. 162
" LX. Rack for holding and storing gas samples . . . 164
" LXI. Ash cylinders after heating, viewed at an inclination 176
" LXII. Ash cylinders after heating, viewed from above. . . 176

Drawings

PAGE

PART VII

Fig. 32. Standard types of steam boilers 3
" 33. Babcock and Wilcox boilers, Department of Mechanical Engineering, McGill University. 15
" 34. General arrangement of experimental boiler plant, Department of Mechanical Engineering, McGill University 17
" 35. Diagram showing boiler efficiency and rate of combustion 33
" 36. Diagram showing boiler efficiency and percentage of fixed carbon. 34
" 37. Diagram showing boiler efficiency and equivalent evaporation. 35

PART VIII

Fig. 38. Diagram of simple form of gas producer 55
" 39. Suction gas producer (Ruston and Proctor) . 58
" 40. Suction gas producer (Pintsch) 59
" 41. Gas producer for lignite briquettes (Koerting) 63
" 42. Twin down-draft gas producers (Power and Mining Machinery Co.). 64
" 43. Double zone gas producer (Westinghouse) 66
" 44. Suction producer No. 1, Department of Mechanical Engineering, McGill University. 75
" 45. Down-draft producer (No. 4), Department of Mechanical Engineering, McGill University. 76
" 46. Forty horse-power gas engine, Department of Mechanical Engineering, McGill University. 77
" 47. Section through gas washer, Department of Mechanical Engineering, McGill University. 77
" 48. General arrangement of experimental producer gas plant, Department of Mechanical Engineering, McGill University. 78
" 49. Diagram showing producer efficiency and coal consumption per B.H.P. per hour. 107

PART IX

Fig. 50. Stansfield pressure regulators, Models (a) and (b) 139
" 51. Vertical section, Koehler calorimeter bomb 146
Fig. 52. Vertical section, Koehler calorimeter 147
" 53. Section of glass parts of Randall and Barnhart gas analysing apparatus. 157
" 54. Diagram of Bone and Wheeler gas analysing apparatus . 161
" 55. Vertical section of Boys' gas calorimeter 165
" 56. General view of Boys' gas calorimeter 167

Index.

List of Mines Branch Publications.

APPENDICES

VOL. III.
  Appendix I
    Coal Washing Tests, by J. B. Porter.
VOL. IV.
  Appendix II
    Boiler Tests and Diagrams, by R. J. Durley.
VOL. V.
  Appendix III
    Producer Tests and Diagrams, by R. J. Durley.
VOL. VI.
  Appendix IV
    Coking Tests, by Edgar Stansfield and J. B. Porter.
  Appendix V
    Chemical Tests, by Edgar Stansfield.

THE
COALS OF CANADA:
AN ECONOMIC INVESTIGATION

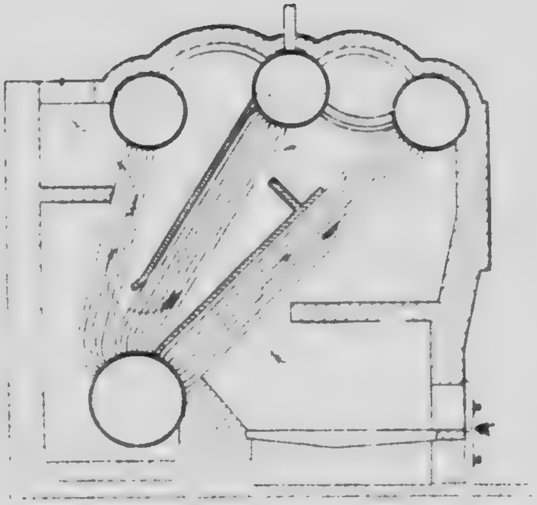
VOL. II

PART VII

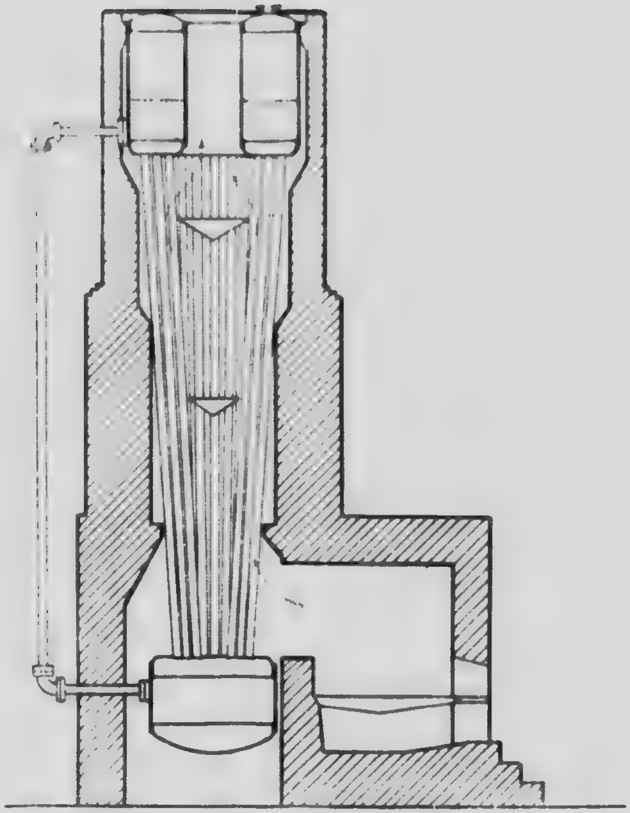
BOILER TESTS

BY

R. J. DURLEY



Stirling water tube boiler.



Cahall water tube boiler.

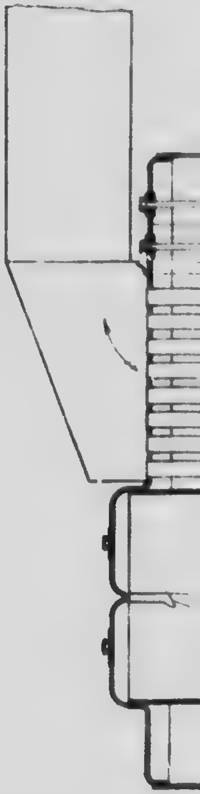
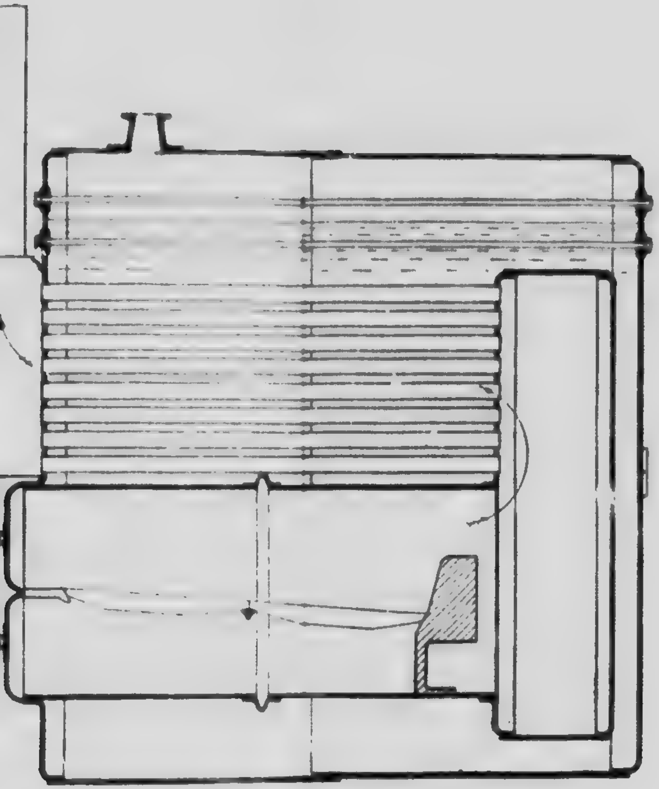
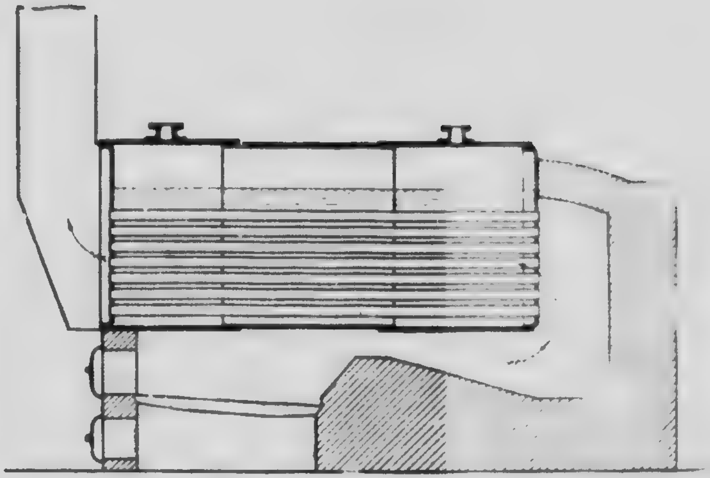


FIG. 32. STANDARD TYPES OF



(c). Scotch marine boiler.



(d). Horizontal return tubular boiler.

YPES OF STEAM BOILERS

THE
COALS OF CANADA:
AN ECONOMIC INVESTIGATION
VOL. II

PART VII
BOILER TESTS
R. J. DURLEY

TYPES OF BOILERS AND THEIR EFFICIENCY

The following brief discussion of certain points connected with boiler practice will possibly be of service to readers who are interested in the quality of Canadian coals but are unfamiliar with steam engineering.

A typical boiler equipment designed for steam raising purposes includes (*a*) the boiler proper, a vessel containing water and steam, capable of withstanding the assigned working pressure, and provided with sufficient external or internal heating surface for the transmission of the heat necessary to convert the water into steam at the desired rate; and (*b*) a furnace, either external or inside the boiler, designed for the combustion of a sufficient amount of the fuel to be used. It is customary to distinguish between water tube and fire tube boilers. In nearly all boilers a large proportion of the effective heating surface is composed of tubes, and these tubes may either be water tubes with water inside and the hot gases arising from the furnace outside, or fire tubes in which the hot gases pass through the tubes, whose outer surface is cooled by the water in the boiler. Fig. 32 shows in diagrammatic form the arrangement of two types of fire tube boiler, together with two well known forms of water tube boiler. It will be noted that the Scotch boiler is internally fired, while the others have external furnaces.

It is, of course, possible to have a well designed boiler, in which the heat developed by the furnace is thoroughly utilized, combined with a furnace of such defective construction that the combustion of the fuel is imperfectly or wastefully carried out. Or, the reverse may be the case; the furnace may be efficient while the boiler is wasteful, and a really economical steam generating plant evidently involves good efficiency of both boiler and furnace.

The *efficiency of a boiler* (including furnace) is generally expressed as a ratio which gives a numerical idea of the economy of the performance of the boiler and is the proportion of the total heat of the fuel which is utilized in the boiler by being employed in heating and evaporating water. The efficiency thus stated evidently takes account of all losses of heat occurring not only in the boiler but also in the furnace. In practice, from 50 to 75 per cent is a fair range of value for this efficiency. In other words, if supplied with coal having a calorific value of 13,000 heat units per pound, a boiler and furnace of ordinary type will utilize from 6,500 to 10,000 heat units for the purpose for which the boiler is designed, the balance of the heat value of the coal being lost or wasted in various ways.

It has been noted that it is possible to have a very economical boiler combined with an uneconomical furnace. The *efficiency of the furnace* taken by itself would be measured by that proportion of the heat value of the fuel which is available for use in the boiler, and this available heat is evidently the calorific value of the fuel minus any heat losses due to incomplete and defective combustion, such losses being chargeable to the furnace proper rather than to the boiler.

The *efficiency of the boiler* alone is evidently that proportion of the heat actually rendered available by the furnace, which is utilized in the boiler and used for raising steam. This efficiency is based on the calorific value of the combustible actually consumed and takes account only of those losses which are chargeable to the boiler itself. The efficiency usually measured in a boile test is connected with the efficiencies just mentioned by the relation

Total efficiency = efficiency of boiler × efficiency of furnace.

In well operated boiler installations of good ordinary design and moderate size, the following table may be taken as giving roughly the distribution o the available heat expressed as percentages of the calorific value of the co used as fuel.

	Per cent
Heating and evaporating water.	60 to 75
Heat lost in flue gases entering stack . .	20 to 10
Heat lost by radiation from boiler.	10 to 4
Heat not developed due to imperfect combustion	5 to 1
Heat used in evaporating moisture in coal and unaccounted for.	5 to 10

The proportion of heat actually used in warming and evaporating wat is usually greater in large boilers than in small, and is generally less the har the boiler is worked, *i.e.*, the more steam is generated per square foot of heat surface per hour. All the best modern types of boiler seem to have about t same maximum efficiency, if well proportioned and worked under suital conditions. Different types of boiler do, however, vary considerably regards first cost, safety, freedom from trouble in operation, ease in cleanin economy in maintenance, and suitability for use with a given kind of By the adoption of special heat saving appliances, together with careful sign and construction, boiler-and-furnace efficiencies as high as 80 per c have been reached in well conducted tests; but this is very unusual in practi

COAL, AND ITS SUITABILITY FOR STEAM GENERATING PURPOSES

The customary classification of coals as anthracite, semi-anthracite, semi-bituminous, and bituminous[1] affords no idea as to the suitability of a coal for steam raising purposes, for coals of all these classes are satisfactorily used for steam boilers; nor can the chemical analysis of a coal be regarded as sufficient to enable us to decide on its steaming qualities. These can only be determined by the practical test of burning the coal in a standard type of boiler-furnace, of known efficiency when worked with some standard coal, and thus measuring the evaporative power.

Neglecting the cost of water, the cost of steam to the power user depends (1) on the amount of heat utilized in the boiler, not from each pound but from each dollar's worth of coal as delivered to the boiler room; (2) on the cost of handling the coal in the boiler room, and (3) on the expense of dealing with the ashes produced. All these items are affected by various physical qualities of the coal and its ash, as well as by its chemical composition. The following notes will give an idea of some of the quantities used in boiler trial calculations and of the factors which influence the steaming quality of coal.

Calorific Value.—The *unit of heat* employed throughout this section of the Report is that commonly employed by engineers, the British Thermal Unit (B.T.U.),[2] which is defined as the amount of heat necessary to raise the temperature of one pound of water through one degree Fahrenheit.[3] Expressed in this manner, the *calorific value* of a coal is measured by the number of B. T. U. that would be generated by the complete combustion of one pound of the coal, and is a number ranging from about 7,500 B. T. U. for coals of poor quality to a maximum of about 15,000 B.T.U. for coals of high grade. Its value depends on the composition of the combustible portion of the coal as well as on the proportion of incombustible matter it contains. The proportion of the calorific value which can be utilized in the boiler will evidently depend on the efficiency of the boiler plant as well as on the nature of the coal and its treatment in the fire.

[1] Kent's classification (Mech. Engrs. Pocket Book, 1904, p. 624) of American coals is

	Carbon Ratio	Fixed Carbon %	Volatile Hydrocarbons %
Hard dry anthracite	100 to 12	100 to 92·31	0 to 7·69
Semi-anthracite	12 " 7	92·31 " 87·5	7·69 " 12·5
Semi-bituminous	7 " 3	87·5 " 0·75	12·5 " 0·25
Bituminous	3 " 0	0·75 " 0	0·25 " 100

The "Carbon Ratio" is the quotient $\frac{\text{Fixed carbon}}{\text{Volatile hydrocarbon}}$

Lignites, of course, belong to a separate class, and are essentially different from any of the above.

[2] In the chemical work connected with this report the gramme-calorie is taken as the heat unit. See Part IX.

[3] The exact value of this quantity depends on the temperature of the water at which the measurement is made. The temperature of maximum density (or 39·1° F.) is commonly taken.

Theoretical Evaporative Power.—Since 966 B.T.U. are required to produce one pound of steam from water at a temperature of 212° F. and at atmospheric pressure (14·7 pounds per square inch)[1], and these conditions are taken as a standard in comparing figures as to steam production, the number of pounds of water which could be evaporated with an ideally perfect furnace and boiler from and at 212° F. will be found by dividing the calorific value by 966. This figure will evidently range from about 8 to about 1 pounds of water per pound of coal.

Chemical Composition.— The effects of the various constituents of a coal on its calorific value are discussed in a later portion of this report. Speaking generally, from the boiler user's point of view it may be said that coals containing a large amount of volatile hydrocarbons are more difficult to burn efficiently than those whose carbon is nearly all in the fixed form. This difference is due chiefly to imperfect combustion of the hydrocarbons, leading to the emission of unburnt gases and smoke.[2]

Coals high in sulphur are not so objectionable for steam raising as for metallurgical purposes, although iron sulphide in the form of pyrites occasionally leads to trouble due to clinkering and the destruction of fire bars.

Chlorine, probably present in coal as common salt, occurs in very small quantities and will give off a small amount of hydrochloric acid when the coal is burnt. It is possible that the corrosion of boiler tubes is partly due to this cause.

The ash or incombustible matter in coal is of very great importance to the boiler user, since as a rule ashes have to be carted away or otherwise dealt with at some considerable cost, and because a fusible ash forms clinkers which stick together in the fire, or adhere to the fire bars or to the brickwork of the furnace, and in many cases are troublesome when the fires are cleaned.

It is hardly necessary to point out that the frequency of cleaning fires has considerable effect on the economy of the plant. While cleaning is going on the fire doors are necessarily open, and the boiler is cooled by the rush of cold air; a good deal of combustible matter is thrown away in the debris removed from the fire,[3] and the amount of heat wasted in the hot ashes is by no means negligible. The proportion of ash in coal is thus one of the most important indications of its quality. The ash in coal consists largely of clayey matter and is, therefore, high in silica and alumina. A coal whose ash is high in iron oxide is usually liable to give trouble from clinkering; but the formation of clinker also depends on the rate of combustion. With a high rate of combustion and a corresponding high furnace temperature, an infusible or difficultly fusible ash may melt and give trouble which would not arise at a more moderate rate of working. Some coals clinker so badly as to render it difficult to use them in certain types of mechanical stokers.

Moisture is always present in coal and diminishes its evaporative power. The moisture in freshly mined coal is gradually lost on exposure to the air until in the ordinary air-dried condition it retains from 2 to 6 per cent. Lignites and lignitic coals contain much larger quantities of moisture.

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[1] See pp. 12 and 13. (Equivalent evaporation from and at 212°).

[2] For recent information on smoke prevention, see Randall and Weeks, Bull 73. U. S. Geol. Survey 1909.

[3] See ash determinations in Summary Record of Trials.

Other Physical Properties. The value of a coal for steam purposes is affected by other qualities. A coal is said to cake when it softens, becomes pasty, and swells up on heating, so that the residual coke left when the gases have been drawn off shows little or no trace of the original pieces or particles of coal. Anthracite and certain other coals show nothing of this property, and coals may be found which exhibit every gradation from a non-caking coal to a coal which softens on heating so as to yield a single coherent mass. The methods of firing adopted with non-caking and with caking coals in a boiler furnace must be different. Non-caking coals should be fired evenly and lightly, and should be disturbed as little as possible after being placed on the fuel bed. A good fireman will direct each shovelful exactly where it is needed to close any hole which may be forming in his fire, and will avoid raking as far as possible, so as to diminish the loss of fuel dropping through the bars. With a caking coal this method of firing is not advisable, and it is a common practice to place such fuel at first just inside the fire door on a dead plate where it can undergo partial distillation, so that the resulting hydrocarbons can pass over the fire and be burned as completely as possible. The coal is afterwards pushed back over the fire bed and a fresh supply put on to coke. Caking coals are, therefore, difficult to fire efficiently, especially as their long flame makes it hard for the fireman to see holes in his fire. The cause of the property of caking in coals is not yet completely known.[1]

The *mechanical strength and hardness* of coal affect its industrial value. The loss from breakage in transportation and handling in the boiler room is serious in many coals. It should be noted that very small sizes of coal and fine dust cannot be burned effectively on ordinary grates, and considerable economy can often be obtained by using screened sizes, utilizing the smalls by themselves by special methods of firing. Most mechanical stokers require coal of more or less uniform size, and uniformity in size is a great advantage in hand firing also.

BOILER FURNACES AND THEIR ADAPTABILITY FOR VARIOUS COALS

No one type of furnace can burn all kinds of coal with maximum efficiency. If the intensity of draft available is known, the grate surface required for the combustion of a given amount per hour of a given coal can be estimated from experimental data. The necessary amount of air for combustion passes much more easily through a bed of coal composed of large pieces than through one of the same thickness but made up of smaller particles. For example, with the finer sizes of anthracite coal it is impossible to obtain a high rate of combustion per square foot of grate unless a high air pressure is available, and the furnace must, therefore, be designed with a large grate surface. With coals which clinker badly a high rate of combustion per square foot is often impossible on account of mechanical difficulties in handling the melted asl with a high furnace temperature. On the other hand, a high furnace temperature is desirable whenever possible, because it is then easier to arrange fo thorough combustion of the inflammable gases arising from the fuel bed. I is found in ordinary practice with a draft of from 0·4" to 0·6" o water that good results are obtained when burning anthracites at from 12 t 15 pounds per square foot of grate per hour, and bituminous coals at from 15 t 20 pounds. Higher figures and better furnace efficiency can be obtained whe conditions are favourable.

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[1] See Part VI.

The furnace of an internally fired boiler is, as a rule, limited in size, an it is difficult to burn bituminous coal in such furnaces to the best advanta unless a suitable combustion chamber is provided in which the gaseous pr ducts of distillation can be burned before they are cooled by contact with th cold sheets and tubes of the boiler itself. For bituminous coal the best re sults are obtained where sufficient surface of hot brickwork is provided and high temperature of the gases is thus maintained until combustion is com plete. A horizontal tubular boiler should be set higher above the grate fo bituminous than for anthracite coal for this reason. The furnaces of exter ally fired boilers in which large areas of brickwork are used have the dis advantage that air tends to [illegible] through the walls (even if these are n cracked or defective) and this reduces the furnace efficiency and general the boiler efficiency also.

Speaking generally, a furnace for burning anthracite coal should have large grate surface and, if possible, should be so arranged that the heat diated directly from the fuel may be taken up by a portion of the boiler he ing surface. For bituminous coals higher rates of combustion are permissil and the furnace should be so designed as to keep the gases hot until they a completely burned, this being the only way of preventing the formation smoke. With such coals, also it is desirable to have some means of admitt a regulated amount of air above the fire, either at the fire door or near the b of the fire, in order that it may mix with the combustible gases at a p where they can burn. Sufficient space above the fuel bed is desirable, e cially for coals high in volatile matter. Attention should be given to method of getting rid of ash and clinker. Rocking or shaking grates sh only be used with coals which are not friable and do not break up when th on the fire, and with coals which do not yield a hard or sticky clinker. caking coals, a proper dead plate should be provided, so that the fuel ma thoroughly coked before being pushed back. With certain clinkering c the use of a steam jet under the grate renders the working of the fire less la ious; there is, however, reason to suppose that this use of steam only creases the efficiency of the process of combustion by the mechanical effec the steam, by keeping the grate bars cool, and by making the remova clinker less difficult. Where mechanical stokers are proposed, it is wel make certain before purchasing that the particular type of stoker sele will work well with the particular kind of coal available.

BOILER TRIALS AND THEIR USE IN TESTING COALS

Tests of two kinds are carried out on boilers, and have for their object either the determination of the steam raising qualities of the fuel employed, or the measurement of the efficiency of the particular type of boiler experimented on. In either case the experiment is conducted in the same way. The boiler-furnace is supplied with a known quantity of fuel, the amount of steam generated is measured, and, in complete tests, the amount of heat furnished by the coal and expended in evaporating the water is determined, together with the various losses of heat which occur. It has already been pointed out that the principal losses are those due to the high temperature of the gases passing to the stack, the heat lost by radiation from the boiler and accessories, and the loss due to imperfect combustion of the fuel, as evidenced by the presence of combustible matter in the ash and refuse withdrawn from the furnace, or sometimes in the flue gases.

The object of the boiler trials discussed in this report was, of course, to compare the behaviour and usefulness for steam raising purposes of the various samples of fuel supplied. In carrying out the trials two objects were, therefore, borne in mind. (1) to determine the amount of water evaporated per pound of coal under conditions as nearly uniform as possible in each case, and (2) to form an opinion as to the behaviour of the coal, the amount of labour required to work it in the fire, and its general suita[illegible]team purposes as evidenced by freedom from trouble arising from clinker, ash, and the like. For the purpose of obtaining information of this kind it is necessary to measure, weigh, or determine: (a) the amount of coal supplied to the boiler in a certain time, and (b) the amount of water turned into steam in the same time. The measurement of these quantities is not so simple as would appear at first sight, because the coal and water are not fed to the boiler at a uniform rate, and, further, it is not possible to work the boiler so that the amount of fuel on the fire at the end of the trial shall be exactly the same as the amount on the fire at the beginning of the trial. The amount of coal fired in a given time is not, therefore, an accurate measure of the amount of coal actually burnt. This cause of inaccuracy is a serious one, but can be overcome by making tests of such length that an error in estimating the condition of the fire at the beginning or end of the trial is negligible as compared with the total amount of coal fired. This is the method adopted in the tests here reported, and is described in the American Society of Mechanical Engineers Rules for conducting boiler tests[1] as the "alternate" method. Another way of dealing with the difficulty is to draw the fire just before the beginning of the test, commencing the test with a weighed quantity of fresh fuel, and drawing the fire again just before concluding the trial. The objection to this method of starting and stopping (known as the A.S.M.E. "standard" method) is that the boiler is inevitably cooled down by an unknown amount during the laborious processes of drawing the fire and starting a fresh one. In any case the fire should be burned low both at the beginning and end of a trial, so as to diminish the possible difference in the amount of fuel on the grate at the commencement and finish of the trial. Evidently the fire at the end will be more charged with ash and clinker than at the beginning, a fact which also requires consideration. Another error arises if the steam is not dry as it leave the boiler; in other words, the steam may carry over into the steam pipe a certain amount of mechanically entrained moisture. In this case the amount of water pumped into the boiler would not be an accurate measure of the amount of water turned into steam, inasmuch as all the water would not have been evaporated. A somewhat similar error is produced if there is a leak in the boiler, blow off pipe, feed pipe, or feed pump, in which case the whole of the water supplied to the feed pump does not reach the boiler or leaks out before being evaporated, and the boiler is, therefore, credited with evaporating water which has never been turned into steam. In a carefully made boiler trial proper precautions have to be taken against the introduction of errors from any of the above-mentioned causes, and this was, of course, done in all the trials under discussion.

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[1] See Trans. A.S.M.E., Vol. XXI, p. 42.

In order to make a fair comparison of the evaporative powers of different coals, it is desirable not only to keep the running conditions as uniform a possible during the whole of the test of each coal, but also to arrange the test so that every sample may have the same chance of developing its maximum evaporative effect. The problem thus becomes a very complicated one The first condition is easy, but to fulfil the second it would be necessary to make a complete series of trials with each coal, at various rates of combustio in the same boiler, and this series would then have to be repeated with boile and especially furnaces of various designs until the most favourable workin conditions for each coal were found The expenditure of time, money, an coal required for this course would evidently be prohibitive in the case o series of tests like the present.

In the series of tests here reported on, the amount of each sample of co available was in many cases sufficient for only one ten hour test (and in case sufficient for more than two tests) on a boiler rated at 60 H.P and even under these conditions the question of the transportation, stora and handling of nearly seventy separate lots of fuel became a sufficien serious one.

After much consideration it was decided that since only one test cou be assured with each coal, all the tests should be carried out at about the sa rate of evaporation. The coals of poorer quality had, therefore, to be burnt a rather higher rate of combustion per square foot of grate than the othe but it vas felt that this condition represented closely that met with in practi for it is rare to find that a steam user changes his boiler arrangement or gr area materially when changing from one coal to another, except when th is a very fundamental difference in the fuel (*e.g.*, when anthracite is to burnt instead of bituminous coal). The rate of evaporation selected and tended in all the trials (about 3¼ pounds of water per square foot of heati surface per hour) was that at which the test boiler was known to give approximately its best efficiency with a standard American coal (Georges Creek, Cumberland, Md.)

In this connexion it should be noted that the boiler in question has a somewhat lower efficiency[1] than could have been obtained had a larger unit been used. The evaporative results are, therefore, all lower than would be obtained with the same coals on tests with a larger and more efficient boiler, but are believed to represent fairly the results to be expected from small units not specially equipped for economical working. The comparative values would probably not have been appreciably changed if the coals had been tested on a larger scale.

It is also possible that higher efficiencies could have been obtained in these tests if it had been possible to make changes in the grate bars, furnace fittings, and brickwork with a view to suiting the peculiarities of each sample, but this course appears inadvisable unless there is enough of each coal to make at least three, or better, four, tests with each, so as to make sure that any changes are beneficial rather than the reverse. On the whole, therefore, it seemed better to retain the same furnace and furnace fittings throughout,[2] even at the risk of placing some samples at a slight disadvantage, so long as the equipment selected was of standard type and reasonably well suited to the majority of ordinary coals. In any case, differences of furnace efficiency due to slight unsuitability of grate bars, or the like, would be masked by any error in the method of working the fire.

The method of firing adopted in the case of any particular coal may have more effect on the result of a boiler test than any other circumstance. It is safe to say that no mechanical stoker yet devised has been able to equal the results obtained by first-class hand firing, and, on the other hand, a poor fireman can often waste more fuel than even a poorly operated mechanical stoker. Hence, it is of the greatest importance, in making comparative tests of coal, to have a good and experienced fireman who is quick to see and adopt the best method of firing for each coal, and his work must be checked by every possible means as the trial proceeds. Whenever possible, a preliminary run should be made, to determine the thickness of fire and intensity of draft which will give the minimum air consumption compatible with good combustion. For this purpose a CO_2 recorder can be made to render valuable service, but proper flue gas analysis by a competent chemist is, of course, preferable. If no preliminary run can be made, all that can be done is to work the fire as the experience of the fireman indicates, changing the conditions of air supply, thickness of fire, etc., at once if the method first adopted gives unsatisfactory results. If possible, the same fireman should make all the tests in the series.

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[1] For description of the boiler and its characteristics, see p. 15. For results of tests made with standard coal, see p. 36

[2] For three tests in which the coal was very small, an exception was made, and special grate bars with narrow air spaces were used. (See Trials 67, 69, and 70.)

The following were adopted as the main conditions governing the series of tests here reported, and are believed to outline the best course that could be taken under the circumstances

(1). In each test the rate of combustion was adjusted to give as nearly as possible the same amount of steam per hour, viz., about 1,800 pounds The boiler efficiency throughout all the tests should, therefore, be approximately the same. The furnace efficiency, however, would tend to be somewhat different in different tests, since different coals would have different rates of combustion, and also on account of variation in the qualities of the coals.

(2). It was decided to use hand firing on fixed grate bars and to emplo the same fireman throughout all of the tests. Fortunately this was possible

(3). The duration of each of the trials was about ten hours. This i enough when burning 250 to 300 pounds of coal per hour to ensure that onl a small error arises in the measurement of the fuel on account of the differenc in the amount of coal on the grate at the beginning and at the end of the tria

(4). In addition to the measurement of coal and water and other necessary observations, note was taken of any difficulties arising during the working of the fire, the amount and nature of clinker formed, and the amou of smoke produced, with a view to obtaining a general idea as to the behavio of the coal in each case. It is hoped that information gathered under th head will be of considerable assistance in forming an opinion as to the value any particular coal.

Brief notes are appended with reference to certain of the results and c culations of a boiler trial

Evaporation of Water. In order to evaporate the water which is pump into a boiler it is necessary to supply sufficient heat to warm this water fr the feed temperature to the temperature at which the boiler is working A further supply of heat must then be furnished in order to turn the heate water into steam, the sum of these two quantities of heat being take the heat given to each pound of water or as the actual heat of evapora of each pound of steam.

Equivalent Evaporation.—As it is difficult to compare the results of t in which the steam pressure and temperature and the feed water tempera are all different, it is necessary to reduce the results of such trials to a com basis. This is done by computing the evaporation from and at 212°F., a n known as the *equivalent evaporation per pound of coal from and at 212°* b obtained. In order to turn one pound of water at 212° F. into stea the same temperature about 966 B. T. U. are needed.

Thus, suppose that in a given trial it was found that the feed temper and other conditions were such that 1,100 B. T. U. were used to turn pound of feed water into steam, and that the actual amount of water orated per pound of coal was 7·4 pounds, the equivalent amount of wa which would be evaporated per pound of coal from and at 212° F. (wi same expenditure of heat) would be 7·4 × 1,100 ÷ 966, that is, 7·4 × 1·13

8·4. The equivalent evaporation worked out for each test thus affords a numerical basis for the comparison of the evaporative powers of all the coals.

Draft. The draft in a boiler furnace is measured by the difference of air pressure under which the air necessary for combustion passes through the layer of fuel lying upon the grate. It is evident that the thicker the bed of fuel and the more closely the particles of coal composing it are packed, the greater will be the draft required. This draft is usually measured in inches of water and is indicated by the difference of water level in the two limbs of a U tube, one being open to the atmosphere, and the other connected to the place where the pressure or vacuum is to be measured. A pressure of 5·2 pounds per square foot is required to maintain a column of water 1" in height, and a draught of 1" of water, therefore, means that the air pressure below the grate is 5·2 pounds per square foot greater than the air pressure above the layer of fuel.

Boiler Horse-power. The figure known as boiler horse-power is commonly used to express the evaporative capacity of the boiler, or its nominal rate of steam production. When expressed in this manner the evaporation of 30 pounds of water per hour from a feed temperature of 100° F. and at a gauge pressure of 70 pounds per square inch is equivalent to one boiler horse-power. The evaporation of 34½ pounds of water per hour from and at 212° F. represents the same expenditure of heat and may be used to represent the same quantity. The horse-power of a boiler is, therefore, found most conveniently by dividing the equivalent evaporation per hour from and at 212° F. by 34½.

Steam Dryness.—The amount of moisture in the steam furnished by a boiler in which the formation of steam is not too rapid will generally be less than 3 per cent, unless the feed water contains substances which cause foaming. In all complete boiler tests the moisture in the steam should be measured, for reasons which have already been pointed out, and this is most easily done by the use of a throttling calorimeter

When steam containing moisture is allowed to escape through an orifice or valve in such a manner that its pressure is reduced, it is found that the steam is drier at the low pressure than was the case originally. Thus, for example, one pound of water at 32° F. requires about 1,150 B.T.U. to convert it into steam 96 per cent dry, or containing 4 per cent of moisture, at 100 pounds per square inch. A pound of such steam, therefore, may be considered as having 1,150 B.T.U. stored up in it. When allowed to blow through a small orifice, in such a way that no heat is lost by conduction or otherwise, into a space where there is a pressure of say 15 pounds per square inch, the moisture will be dried up or evaporated until the heat stored in each pound is the same as before. This will occur (with a lower pressure of 15 pounds per square inch) when the moisture in the steam has just been evaporated, as may be verified by calculating the total heat of one pound of dry steam at a pressure of 15 pounds per square inch. This will be found to amount also to 1,150 B.T.U.

In measuring the dryness of steam by means of the throttling calorimeter, the wet steam is throttled until it is completely dry or even a little superheated. From observations of the temperature and pressure at which this condition occurs, the original state of the steam is calculated by the aid of steam tables.

Air Used for Combustion.—The combustion of coal in a boiler furnace should be carried on with only a slight excess of air supply over the amount just required for complete combustion. Thus, the flue gases from the furnace should show only a small amount of free oxygen, the bulk of the oxygen in the air used having combined with carbon or hydrogen from the fuel to form either carbon dioxide or steam. An excess of air carries away and wastes heat which might otherwise be utilized.

The direct measurement of the air entering a boiler furnace by means of an anemometer is difficult and unsatisfactory, and it is customary to control and measure the amount of air used by the results of chemical analyses of the flue gas.[1] Assuming that a satisfactory sample of the flue gas has been obtained and accurately analysed, the weight of carbon contained in 100 pounds of the gas can be calculated, and hence the amount of ai used per pound of carbon burnt. The amount of carbon burnt per pound of coal fired being known, it is easy to work out the number of pounds of air drawn into the furnace per pound of coal fired. The heat lost or carried away to the stack by the hot flue gases can then be calculated if the flue gas temper-ature and that of the boiler room or air supply to the boiler are known. Th amount of air which would just suffice to burn one pound of coal completel is usually from 10 to 12 pounds, depending on the composition of the coal. Good results are obtained with an ordinary boiler furnace when the ai used is from 15 per cent to 25 per cent in excess of this, say 12 to 16 pounds o air per pound of coal. In such a furnace it is seldom possible to obtain goo combustion with a smaller excess of air than the above. Some coals are ver difficult to work without admitting a considerably greater excess of ai

Radiation Losses Very little reliable information is available regardin the heat lost by radiation from steam boilers, as the quantity in question very difficult to measure experimentally. The A.S.M.E. code of rules boiler trials provides that radiation losses shall be included with the los due to unconsumed hydrocarbons in the flue gas and other indeterminat losses. An attempt at measuring the radiation loss in an ordinary boiler ma be made by partly bricking over the grate, and determining the amount coal required to maintain a constant steam pressure (and presumably a con stant temperature also) during a sufficiently long period of time. The ave age of seventeen trials made by Donkin and Kennedy on different boile in this manner gives about 5·8 per cent of the total heat of combustion. Th radiation loss is, however, proportionately larger in small than in larg boilers, and larger in boilers with brick settings than in boilers having les radiating surface. Radiation losses up to 10 per cent of the heat develope by the coal at the rated capacity of the boiler are probably not uncommon.

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[1] For flue gas analysis methods adopted in these tests, see Part IX "Engineering," 1897.

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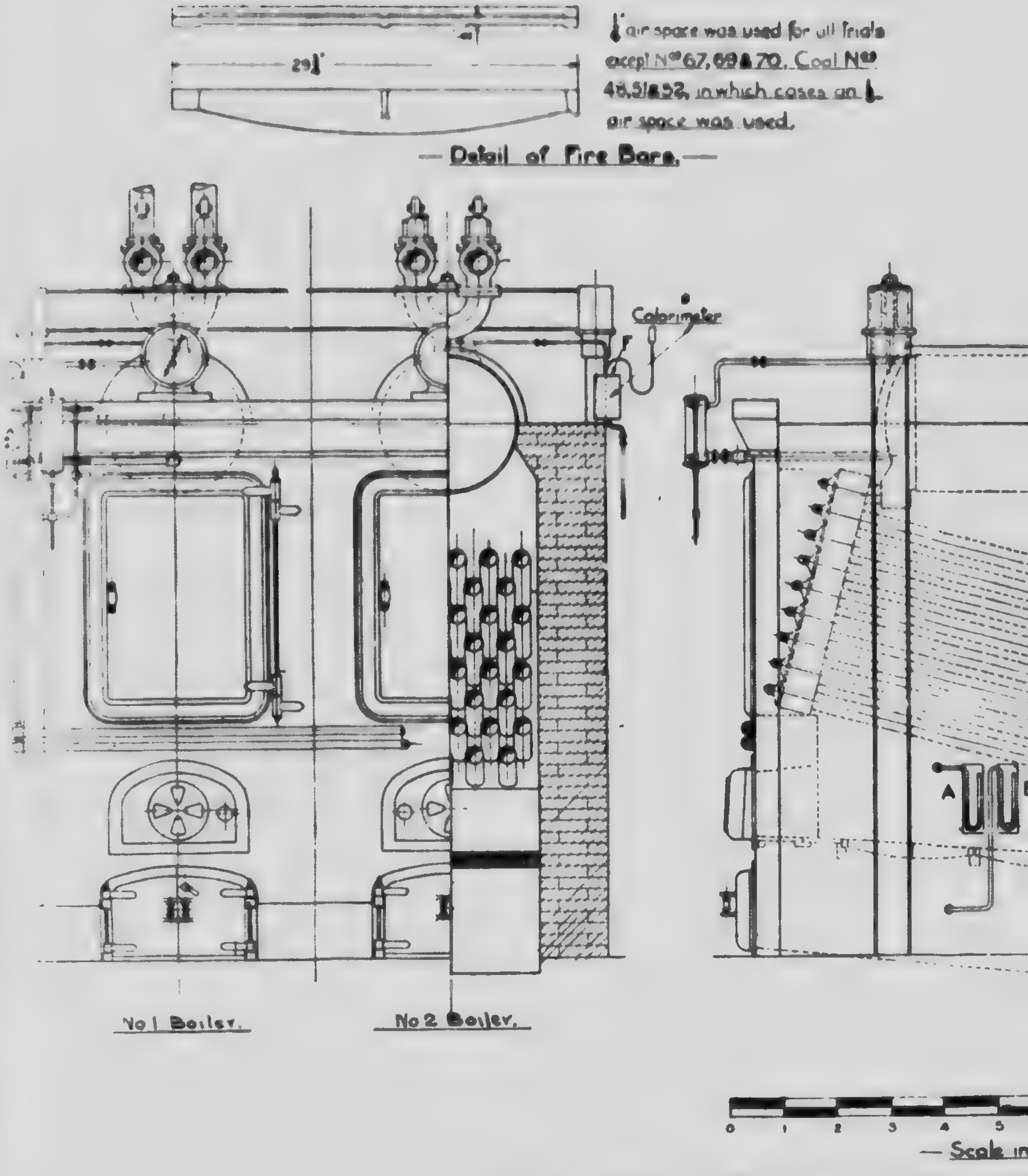
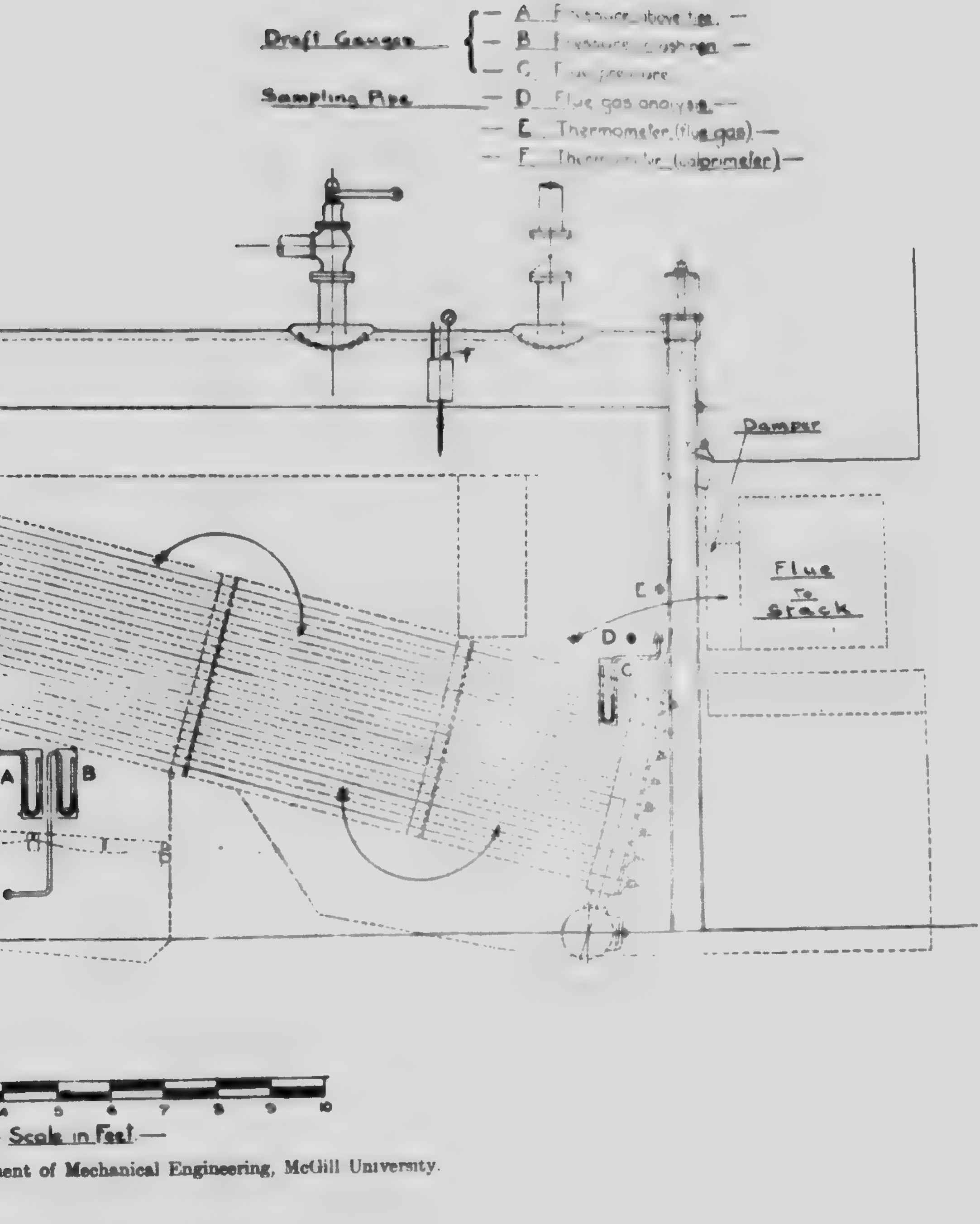


Fig. 33. Babcock and Wilcox boilers. Department of Me



ent of Mechanical Engineering, McGill University.

EQUIPMENT

BRIEF DESCRIPTION OF PLANT AND APPARATUS USED FOR BOILER TRIALS

The boiler on which the tests here reported were made was No. 2 of a pair forming part of the experimental equipment of the Department of Mechanical Engineering, McGill University. It is of the Babcock and Wilcox single drum type and the leading dimensions and particulars are as follows:—

Heating surface (tubes)	sq. ft.	593
" " (drum etc)	"	46
" " **Total**	"	639
Grate surface	"	16·79
Width of grate	feet	3·25
Length of grate	"	5·167
Height, grate to lowest tier of tubes	inches	at front 24 at back 15
Approximate width of air spaces		¼" (and ⅛" in special cases)
Proportion air space to grate surface		30% (and 15% in special cases)
Mean diameter of steam drum	inches	36 (inside)
Length of steam drum exposed	feet	12·37
Number of tubes		40
Diameter of tubes (external)	inches	4
Length of tubes exposed	feet	13·66
Ash pit below grate surface	inches	at front 25 at back 22
Total water space	cub. ft.	110
Total steam space	"	31
Ratio heating surface to grate surface		38·1 : 1
Working pressure	lbs. per sq. in.	120

When the water stood at 4½" in the gauge glass the boiler contained 1,720 pounds of water, each inch in the gauge glass corresponding to a weight of 152 pounds of water.

The general arrangement of the boiler is shown in Fig. 33, and it was set in battery with another boiler of exactly the same make and construction, except that No. 1 boiler was originally fitted with a Jones stoker (not shown in the drawings), and No. 2, on which the experiments were made, was fitted with a plain cast iron grate. The furnace of No. 2 boiler, as will be seen from the drawings, is of the usual type, and the baffling is the standard Babcock and Wilcox arrangement consisting of firebrick tiles forming partitions placed transversely to the tubes with the smoke connexion to the flue in rear. The furnace walls are lined throughout with firebrick. Provision was made for blowing steam under the grate when necessary, and also for the use of water in the ash pit—with some of the coals tested the necessity of a steam supply under the grate was amply demonstrated. The steam used under the grate during the trials was not charged against the boiler, because the desired effect could have been obtained by other methods not involving additional expense in operation.

The furnace door was of cast iron, hinged, and provided with an adjustable grill or louvre opening for admission of air above the bars, and with a perforated internal baffle plate. There was no other arrangement for admitting air above the grate.

The brickwork of the furnace and boiler was thoroughly repaired shortly before the tests and was in good order throughout the trials.

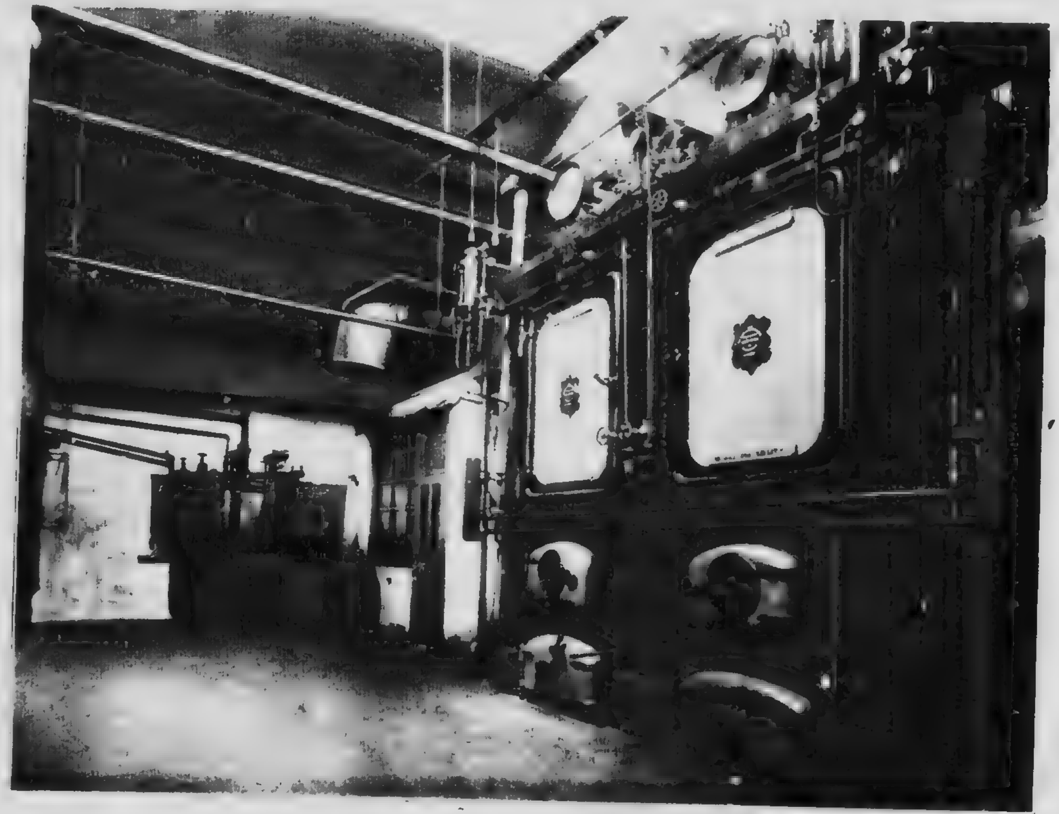
Stack. The boiler was connected by means of a brick flue to a stack about 100 feet high and 36" square inside. This stack also took flue gases from other boilers in the same boiler room, but as these boilers were not working hard during the trials one being laid off and two only used for auxiliary purposes, and as anthracite coal was burnt in these, there was no difficulty in obtaining information as to the smokiness of the coals under test. The furnace was not equipped with any special form of smoke preventer as it was felt that observations on the smoke produced by the various coals would be of greater interest if the boiler were working under conditions usual in practice. The general arrangement of the boiler plant is shown in Fig. 34 and in Plate XLVI

Draft. Provision was made for forced draft by means of a fan driven by a 4" × 4" high speed engine. In this way any air pressure in the ash pit up to 1½" of water could be obtained, and this equipment was found very necessary in the case of certain coals. The steam used by the forced draft fan engine was not charged against the boiler, as a sufficient draft could have been obtained for any of the coals used had the stack been of sufficient capacity. The natural draft actually available was such as to give about 0.4 at the damper under favourable conditions. Draft gauges were fitted below the grate, above the fire, and at the damper. These draft gauges (shown at A, B, and C, Fig. 33) were of the ordinary U tube form, and the differences of pressure were read directly in inches of water. The dampe was of the sliding type and adjusted by hand.

Steam Pipe Arrangement. The steam pipes in the boiler roo [illegible] anged as a ring main, and are shown in Fig. 34; they were properly covered during the tests. A portion of the steam produced by the boiler during the tests wa delivered to the electric generating station of the University. At times, how ever, of very light load on the power plant, the boiler under test furnishe more steam than was required for the engines, in which case it was allowed to escape to the atmosphere through the safety valves.

Dryness of Steam. –The dryness of the steam produced was measure by a Peabody throttling calorimeter arranged as shown at F in Fig. 33. Th results of a large number of careful trials which had been made on No. [illegible] ale previous to the tests here reported, show that this boiler can be depended on t give commercially dry steam at rates of evaporation considerably greater tha those used during the official tests. This fact was borne out by all the calorimeter determinations.

Boiler Feeding Appliances. Two wrought iron rectangular weighing tanks, each 25" × 25" × 24", were used to receive water drawn from the city mains. Each was mounted on Fairbanks standard platform scales of 1,000 pound capacity reading to one-half pound. The tanks had quick opening valves



Boiler room   Experimental Steam Plant   Department of Mechanical Engineering   McGill University

discharging into a larger tank below them from which the feed pumps drew. In this lower tank a wooden T gauge was provided to which the water level was adjusted at the beginning and end of the trial.

Two feed pumps were provided, each of the duplex steam driven type: one 6″×4″×6″ and one 5¼″×3″×6″. Their connexions were such that the pump not in use could be completely cut off by blank flanges. This arrangement was also carried out with the feed piping, all branches through which leakage could possibly occur being blank flanged during the tests.

The blow off piping of the boiler was arranged so that the open end was visible and was disconnected from the blow off line.

Coal Scales, etc.—Coal was weighed in a box, placed on a Fairbanks standard platform scale of 2,000 pounds capacity.

Sample Cans.—Sample cans provided with tight fitting covers were used for taking samples of the coal.

Flue Gas Sampling Apparatus.- The flue gas analysis was carried out on samples of flue gas, which were taken periodically from a stream continuously drawn from the boiler outlet by a water jet exhauster. The chemical apparatus and methods of analysis are fully described in Part IX of this report. The sampling tube, placed in the outlet from the boiler into the main flue and close to the damper (at **D** Fig. 33), consisted of a piece of 1¼″ seamless steel tube closed at one end and perforated with a series of holes $\frac{5}{16}''$ in diameter and about 6″ apart. This sampling tube extended across the opening fron the boiler into the flue.

The standard sampling apparatus recommended by the American Society of Mechanical Engineers was not employed, because it would have been very difficult to install in the position available, and because as a result of a series of experiments made with a view to determining the effect of hot flue gases on iron, it was thought advisable to try an enamelled surface for the collecting tube. This material was found to give results which agreed well with those obtained from water-cooled collecting tubes, and the difficulties arising from scale, etc., in the water cooled tubes, were in this way avoided. It was, therefore, finally decided to use a steel tube, enamelled inside and out and arranged as described above. This was found to give very satisfactory and consistent results, the enamelling being done, of course, after the $\frac{5}{16}''$ holes were drilled, and in such a way that no metallic iron was exposed to the action of the hot flue gas.

As a general check on the flue gas analysis, a Simmance-Abady CO_2 recorder was installed in the boiler room, and its indications, while not in exact numerical agreement with the results of the gas analysis as far as percentage of CO_2 was concerned, served to show whether the chemical results on a comparatively small number of samples really gave representative figures. Considerable trouble was experienced in the operation of the CO_2 recorder, and in certain of the trials its use had to be discontinued. The difficulties encountered arose chiefly from dust in the flue gas sampled, owing to ineffective filtration in the apparatus.

Pressure Gauges.—Standard gauges were used for pressure indications, and were tested from time to time on a Crosby dead weight gauge tester.

Thermometers.—A Hicks thermometer was used for feed water temperature, and placed in the feed water tank from which the pumps drew. The errors of all thermometers used were determined by comparison with certified Hicks standard thermometers. A Hohman and Maurer gas filled mercuria thermometer was used for flue gas temperature determinations.

METHOD OF CONDUCTING TESTS AND MAKING MEASUREMENTS LOG AND CALCULATIONS FOR ONE TRIAL

METHOD OF CONDUCTING TRIALS

The trials were conducted in accordance with the system recommende by the Committee of the American Society of Mechanical Engineers in thei code of 1909[1]. The total number of tests made (including those made fo comparison with standard coal) was seventy-two, and it was found impossible to obtain the samples of coal from the east and from the west of Canad with sufficient rapidity and regularity to enable all of these to be made i one season. Thirty-nine of the tests were, therefore, made during th summer of 1907, thirty-seven during the summer of 1908, and the remainde subsequently.

The equipment of the boiler room having been described in the previou section, the following paragraphs give a brief account of the organization an methods adopted in making the tests.

DUTIES OF STAFF

Four observers and one fireman were employed in each trial. T observers' duties were:

Observer No. 1. Conducted the trial, observed and directed the worki of the fire, entering all events in the log sheet, weighed coal fired and ash a clinker removed. Took samples of coal and refuse.

Observer No. 2. Took charge of weighing feed water, adjusted the l of water in feed tanks and in boiler, and superintended the working of feed pump.

Observer No. 3. (Chemist). Was responsible for sampling and anal of flue gases.

Observer No. 4.—Read all pressures and temperatures, observed recorded steam dryness, intensity of draft, and damper opening.

The fireman, in addition to firing as directed, attended to the forced d apparatus and steam jet under the grate (when used); he also assiste handling the coal to and from the scales.

Most of the observations were taken at 15 minute intervals.

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[1] See Trans. A.S.M.E., Vol. 21 pp. 34-41; also Vol. 6, pp. 256-267.
See Vol. I, pp. 4 and 5.

GENERAL PRECAUTIONS

Before each trial the boiler tubes and headers were blown as clean as possible, and the grate and brickwork freed from clinker, etc. The brickwork was in every case thoroughly heated before commencing a test. Before each series of trials the brickwork of the boiler was put in thorough repair, and the boiler and connexions were tested for tightness.

WEIGHING AND HANDLING COAL

From each lot of coal, after examination, treatment, mixing, and sampling by the staff in charge of the chemical and coal-washing portion of the investigation, a sufficient quantity was taken, bagged, and delivered to the boiler room. The means of identification for the information of the boiler room staff was a label affixed to each bag, giving the serial number of the coal. (See Column 2 in Table IV.) The amount of coal in all but one or two cases was enough not only for the ten-hour trial, but also for a preliminary run of a length sufficient to give the staff an opportunity of finding an appropriate method of firing and working the coal in the furnace.

Starting with a banked fire from the previous day's run, the tubes were cleaned, the fire was broken out, and firing was commenced with the coal to be tested. When in proper condition, and generally about one hour before commencing the test, this fire was burned down and cleaned, the trial being actually started when the clean fire was in a suitable condition to be judged.

During the trial the coal was fired, and the fire sliced, broken up, and cleaned as found necessary. In every case, however, the fire was again cleaned about one hour before the conclusion of the trial, and was then worked so as to bring it at the end of the test into as nearly as possible the same condition as at the beginning.

The coal was emptied from the sacks into a wooden shovelling bin mounted on scales and holding about 120 pounds. The time at which this bin was emptied was noted as the time at which a certain weight of coal had been fired. Check weights were taken every half hour.

After emptying each sack a sample of about 20 pounds was taken from the bin and placed in a special sample box. The contents of the sample box were afterwards forwarded to the Chemical Department for analysis. On this analysis the figures for the percentage of moisture (Column 11, Table IV) were based.

The whole of the ash and clinker formed during the trial was weighed and forwarded to the Chemical Department for analysis.

MEASUREMENT OF WATER

Water from the city mains was admitted as required into a weighing tank mounted on scales. After weighing each tankful of water it was discharged into the feed tank from which the feed pump drew. A wooden T gauge in this feed tank marked a level to which the water was brought at the commencement and also at the end of the trial. The gauge glasses on the boiler were, of course, also marked, and allowance made for any difference in level at the beginning and end of each interval.

The feed water scales, as well as those used for coal weighing, were carefully tested with standard weights before each series of trials and at intervals during the progress of the work.

TEMPERATURE OF FEED WATER

The temperature of the feed water was taken by a Hicks' thermometer immersed in the water in the feed tank. With the low feed temperatures actually used, there was no perceptible change in temperature while the water was pumped to the boiler.

QUALITY OF STEAM.

Pressure.—The pressure of the steam at the calorimeter was read upon a standard Schaeffer and Budenberg pressure gauge. This gauge was carefully tested from time to time upon a Crosby standard gauge tester, and its error determined.

Dryness.— The amount of moisture present in the steam was computed from observations taken with a Peabody throttling calorimeter. The pipe leading to the calorimeter was taken directly from the steam drum of the boiler, and steam was passed through the calorimeter continuously during the test.

DRAFT

The draft was measured by means of U tube gauges filled with water. These tubes were placed in order to record the draft:

(a) under the grate.
(b) over the grate.
(c) at the back of the boiler, close to the damper.

FLUE GASES

The temperature of the flue gas was observed in the opening to the main flue (at E Fig. 33) close to the damper. The thermometer used was a Hohman and Maurer gas filled mercury thermometer, which was adjusted to read correctly at 212° F.

A portion of the flue gas was withdrawn continuously through a sampling pipe leading from a point at the back of the boiler close to the damper opening, the suction being produced by means of a water aspirator. Sample bottles were filled from a tee on this sampling pipe. The sampling apparatus has already been described in detail (see p. 17).

A sample of about 300 c.c. was taken from the sampling pipe every fifteen minutes for analysis while the trial proceeded. As the results of these analyses were used for controlling the method of firing and treatment of the fire, these samples as a rule were not taken while the fire was being cleaned or when it was in defective condition. The loss of heat due to the escape of hot flue gas, as given in Column 39, Table IV, will, therefore, be rather less than the true amount. The figures in columns 36 and 37 will, however, not be affected by this circumstance. For full details of methods of chemical analysis in the boiler room see Part IX of this Volume

RESULTS OF BOILER TRIAL NO. 58

In order to illustrate the methods adopted and the results obtained during the tests the complete log of one trial is annexed, together with the resulting calculations worked out in detail. This trial was made on a sample of coal from Cape Breton, and was taken as being fairly representative.

The log is followed by two forms, the "Summary of Observations" (Form A) and the "Summary of Results" (Form B); most of the items in these are self-explanatory. A complete series of such summaries and logs for all the trials will be found in Vol. IV of this report.

Explanations as to the methods of calculation by which the figures in Form B were obtained are given below, the calculations applying, of course, to trial No. 58 for which the log and summaries are given here.

LOG OF EVENTS

Trials of No. 2 Babcock and Wilcox Boiler with No. 36 coal.
Date, July 31, 1908. Trial number, G. C. T. 58
Observations of general conditions.
Observer, J. Blizard.

NOTES.—No. 1, B. and W. boiler working. Weather close and warm. Coal of medium size, not much small stuff. Fair amount of slate-like substance.

General Notes.

Time.

7.30 a.m. Fire cleaned, and made up with No. 36 coal. Pressure 85 pounds per square inch.

7.50 Tubes blown.

8.40 Started trial. Fire 2" well burnt through; flame at back. Keeping thin fire (3"). This coal burns with much flame and smoke.

9.30 Grill half open. Does not coke at all.

10.05 Grill wide open.

12.10 p.m. Slice bar put into fire and found some hard clinker on bars. Did not remove. So far rake has not been put into fire, coal not coking at all.

2.27 Sliced fire.

3.27 Sliced fire, removed 40 pounds clinker. Clinker when hot seems to be in plastic cakes spread over grate.

5.30 Fire cleaned. Removed 70 pounds clinker in large slabs which harden on cooling. Bluish in colour. Not very difficult to remove, but coal could not be used on shaking grate.

6.40 Trial finished, fire as at start. 52 pounds ash raked from ash pit Blow off examined and found tight.

Ash and Clinker

	Tare	Gross	Net	
3 27 p.m.	—	. . .	40	Fire sliced
5.30 p.m.	75	145	70	Fire cleaned
			110	pounds clinker
6.00 p.m.	75	127	52	pounds ash raked from beneath bars.
			162	pounds ash and clinker.

Coal Fired

Trial on No. 2 Babcock and Wilcox boiler with No. 36 coal.

Date, July 31, 1908. Trial number, G. C. T. 58.

Observations on coal.

Observer, J. Blizard.

Notes.—Coal fired before trial commenced, 7·32 to 8·40 = 246 lbs.

TABLE I

Detailed Record of Coal Fired.

Time	Nos. of Sacks	Coal Bin			Coal Fired in Interval	Total Coal Fired
		Tare	Gross	Net		
a.m.						
8 40	2 (cont'd)	132	182	50		.
8 45	3, 4, 5	132	549	417	50	50
9 15			328		221	271
9 45			195		133	404
9 55		132	552	420	63	467
10 25			[illegible]		146	613
10 55			2.		152	765
11 15	6, 7	132	451	319	122	887
11 45			329		122	1009
p.m.						
12 15			174		155	1,164
12 17	8, 9, 10	132	532	400	42	1,206
12 45			369		163	1,369
1 15			196		173	1,542
1 30	11, 12. 13	132	541	409	64	1,606
2 0			436		105	1,711
2 30			286		150	1,861
3 0			185		101	1,962
3.10	14, 15	133	462	329	53	2,015
3 40			328		134	2,149
4.15	16, 17	132	566	434	195	2,344
4 45			416		150	2,494
5 15			312		104	2,598
5 30	(Before cleaning)		290		22	2,620
5 45	18	132	408	276	158	2,778
6.15			265		143	2,921
6.40			232		33	2,954

Gas Analysis

Trial on Babcock and Wilcox No. 2 boiler with No. 36 coal
Date, July 31, 1908. Trial number, G. C. T. 58.
Observations of flue gas analysis
Observer, E. J. Conway.

TABLE III

Detailed record of Gas Analysis.

Time	CO_2	CO_2+O_2	O_2	CO_2+O_2+CO	CO	N	Remarks
8 40	10·8	16·6	5·8	18·4	1·8	81·6	
9 10	10·1	17·3	7·2	19·0	1·8	81·0	
9 40	10·2	19·0	8·8	19·4	0·4	80·6	
10 10	12·0	18·5	6·5	18·7	0·2	81·3	
10 40	9·2	19·5	10·3	19·7	0·2	80·3	
11 10	9·5	18·3	8·8	19·4	1·4	80·6	
11 40	8·9	19·0	10·1	19·9	0·9	80·1	
12 10	11·2	16·6	5·4	19·3	2·7	80·7	
12 40	10·9	16·3	5·4	19·2	2·9	80·8	
1 10	11·6	17·1	5·5	18·6	1·5	81·4	
1 40	9·2	18·1	8·9	19·7	1·6	80·3	
2 10	9·0	15·0	6·0	19·5	4·5	80·5	
2 40	9·0	19·0	10·0	19·2	0·2	80·8	
3 10	7·8	19·9	12·1	19·9	0·0	80·1	
3 40	12·5	17·8	5·3	19·2	1·4	80·8	
4 10	8·6	18·7	10·1	19·3	0·6	80·7	
4 40	10·5	18·5	8·0	19·0	0·5	81·0	
5 10	8·1	19·5	11·4	19·7	0·2	80·3	
5 45	8·4	17·9	9·5	18·8	0·9	81·2	After cleaning fire.
6 10	9·0	17·8	8·8	19·0	1·2	81·0	
Mean Value	9·8		8·2		1·2	80·8	

BOILER TRIAL NO. G. C. T. 58. -FORM A.

Summary of Observations

Date, July 31, 1908. Boiler B. & W. No. 2 at McGill University
Commenced 8.40 a.m. Ended 6.40 p.m. Duration 600 minutes.

General

1. Method of stoking—hand, spreading on alternate sides.
2. Kind of draft—natural.
3. Condition of boiler and date of cleaning—thoroughly cleaned May 1908.
4. Tubes cleaned, 7 50 a m
5. Fire cleaned, 7.30 a.m., 5.30 p.m.

Fuel—

6.	Kind of coal—No. 36. Dominion Coal Co., Sydney, No. 7 mine.		
7.	Analysis of dry coal by weight (%), C = 76·7, H = 5·[illegible], S = 2·4, N = 1·6, O = 8·4, ash = 5·9.		
8.	Calorific value of dry coal B.T.U. per lb.		13,860
9.	Moisture in coal as fired	%	2·7
10.	Weight of coal fired (lbs.)		2,954
11.	Combustible matter in ash and clinker	%	14·6
12.	Weight of clinker (lbs.)		110
13.	Weight of ash (lbs.)		5

Air and Flue Gas—

14.	Air pressure under fire (inches of water).	0·02
15.	" " above " " "	0·18
16.	" " at damper " "	0·28
17.	Amount of damper opening, full, ½ open 5.55 p.m. to 6.10 p.m.	
18.	Temperature of air in boiler house (°F.).	90·
19.	Flue temperature (°F.)	610
20.	Analysis of dry flue gas by volume %, CO_2 = 9·8, O = 8·2, CO = 1·2, N = 80·8.	

Water and Steam—

21.	Temperature of feed water (°F.)	75·
22.	Total weight of feed water (lbs.), corrected for difference of level	17,691·[illegible]
23.	Water level in gauge at start (inches)	[illegible]
24.	" " " " " finish (inches)	
25.	Correction for difference of level (lbs.), included above	[illegible]
26.	Steam pressure by gauge (lbs. per sq. in.)	14[illegible]
27.	Barometer reading (inches)	29·50
28.	Pressure in calorimeter by gauge (lbs. per sq. in.)	1[illegible]
29.	Temperature in calorimeter (°F.)	29[illegible]

Notes—

Coal burns with much flame and smoke. Grill open over fire. Not coking at all. Clinker bluish, plastic when hot; easily removed but coal could not be used on a shaking grate. Fire cleaned out once, sliced three times.

Weather close and warm.

Proximate analysis	Fixed carbon	[illegible]
	Volatile matter	[illegible]
	Ash	5·9

Signed, JOHN BLIZARD.

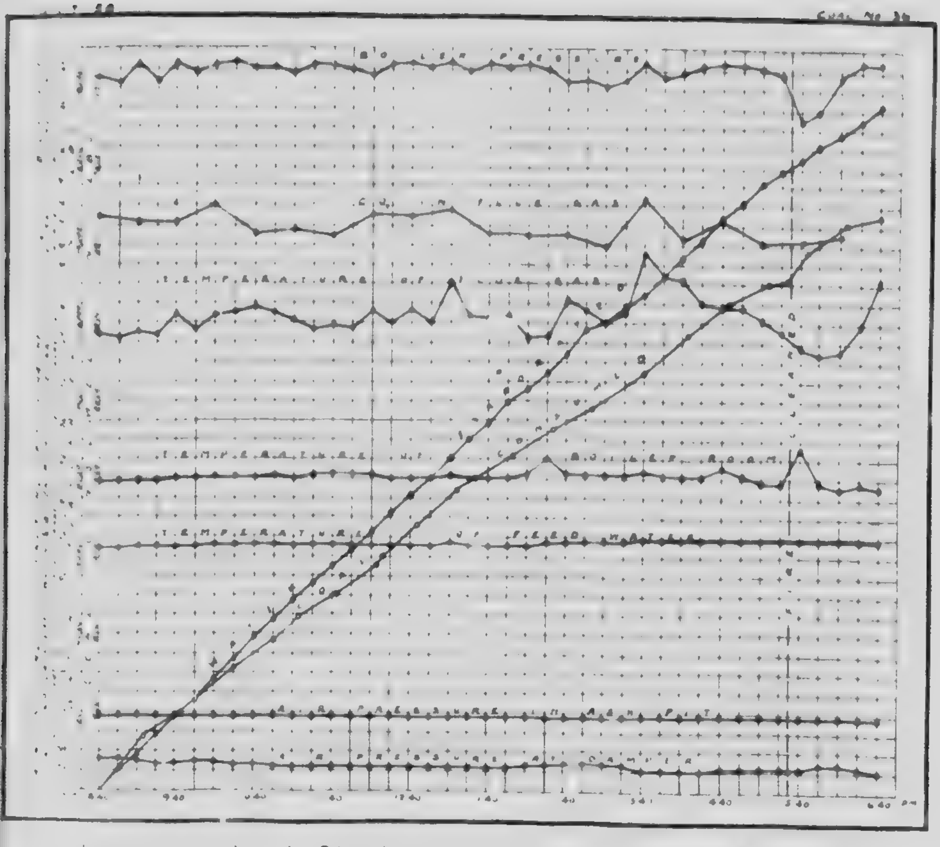

Diagram typical of the 72 boiler trial curve sheets in Appendix II Vol. IV

BOILER TRIAL NO. G. C. T. 58—FORM B.

Summary of Results

Trial on Babcock and Wilcox No. 2 boiler at McGill University.

To determine quality of coal.

Kind of fuel, No. 36 coal. Kind of furnace, fixed bars, 30 per cent ai space.

Method of starting and stopping test, alternate (A. S. M. E.)

Grate surface (square feet), 16·79. Water heating surface (square feet), 639

Superheating surface (square feet), nil.

Barometer at start, 29·64, at finish, 29·54, mean 29·59.

Total Quantities

1.	Date of trial. . .	31/7/08
2.	Duration of trial (hours).	10·0
3.	Weight of coal as fired (lbs.).	2,951
4.	Percentage of moisture in coal as fired (%)	2·7
5.	Total weight of dry coal, fired (lbs.).	2,874
6.	Total ash and refuse (lbs.).	162
7.	Percentage of ash and refuse in dry coal (%), (a) from analyses, 6·9, (b) weighed.	5·64
8.	Total weight of combustible consumed (lbs.), from analyses	2,676
9.	Total weight of water fed to the boiler corrected for difference of level (lbs.).	17,691
10.	Equivalent water evaporated into dry steam from actual feed water temperature and boiler pressure (lbs.)	17,620
11.	Equivalent water evaporated into dry steam from and at 212° F. (lbs.).	20,920

Hourly Quantities—

12.	Dry coal fired per hour (lbs.).	287·4
13.	Dry coal per sq. ft. of grate surface per hour (lbs.)	17·1
14.	Water evaporated per hour corrected for quality of steam (lbs)	1,762
15.	Equivalent evaporation per hour from and at 212° F. (lbs.).	2,092
16.	Equivalent evaporation per hour from and at 212° F. per sq. ft. of water heating surface (lbs.)	3·27

Average Pressures, Temperatures, etc.—

17.	Steam pressure gauge (lbs. per sq. in.).	118·4
18.	Temperature of feed water entering boiler (deg. F.)	71·5
19.	" " escaping gases from boiler (deg. F.).	616
20.	Pressure of draft between damper and ash-pit (ins. of water).	0·2
21.	Percentage of moisture in steam.	0·6

Horse-power—		
22.	Horse-power developed (Item 15 ÷ 34½)	60·5
23.	Builders' rated horse-power.	60
24.	Percentage of builders' rated horse-power developed.	101
Economic Results—		
25.	Water apparently evaporated under actual conditions per lb. coal as fired (Item 9 ÷ Item 3)	5·99
26.	Equivalent evaporation from and at 212° F. per lb. coal as fired (Item 11 ÷ Item 3)	7·08
27.	Equivalent evaporation from and at 212° F. per lb. of dry coal (Item 11 ÷ Item 5)	7·27
28.	Equivalent evaporation from and at 212° F. per lb. of combustible consumed (Item 11 ÷ Item 8)	7·83
Efficiency—		
29	Calorific value of dry coal per lb. (B.T.U.)	13,860
30.	" " of the combustible per lb. (B.T.U.)	14,740
31.	Efficiency of boiler (based on combustible consumed (%)	51·4
32.	" " " including grate (based on dry coal) (%)	50·6
Flue Gases—		
33.	Dry flue gas per lb. carbon (from gas analyses) (lbs.)	22·6
34.	" " " " " combustible consumed (from gas analysis) (lbs.)	18·6
35.	Dry flue gas per lb. dry coal (from gas analyses) (lbs.)	17·3
36.	Proportion of heat of fuel in escaping dry flue gases (%)	15·7

Signed, John Blizard.

CALCULATIONS

Calculations for Trial No. 58, leading to Figures given in the Summary of Results Form B.

Items Nos. 1 to 4B[1] require no explanation.

Item 5B.—Total weight of dry coal fired. This is found from the total weight of coal fired, less weight of moisture, and is equal to:—

Total coal fired (Item 3B) × (1 − moisture per pound coal, from Item 4B)

2,954 × (1 − 0·027) = 2,874 pounds

Item 7B.—Percentage dry coal unconsumed.

The refuse withdrawn from the ashpit always contains a proportion of combustible matter in addition to the ash, or really incombustible part of the fuel. A certain amount of the ash in the coal burnt is always lost by being carried off in the form of dust by the flue gases or otherwise. The actual weight of refuse taken from the ashpit is, therefore, less than the weight of that part of the fuel which is not consumed. Item 7A gives the proportion of the dry coal which is not consumed, estimated from the analysis of the refuse removed; Item 7B gives the proportion as actually weighed, and is, of course less than 7A. In calculations based on combustible consumed, 7A has bee used throughout.

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[1] Items taken from the "Summary of Observations" are marked A (Item 12A, etc.), those from the "Summary of Results" are marked B.

Item 7A.—The material removed from the ashpit during the trial contained 14·9 per cent (Item 11A) of combustible matter and 100 − 14·9 o 85·1 per cent of real ash. But the dry coal as analysed contained 5·9 pe cent of real ash, and, therefore, must have contained $5 \cdot 9 \times \frac{100}{85 \cdot 1}$ or 6·9 per cent of refuse consisting of 14·9 per cent of combustible matter and 85·1 per cent of ash. Also 100 − 6·9 or 93·1 per cent of the dry coal fired w actually consumed as combustible.

Item 7B.—The percentage as determined from the weight of refuse actually taken from ashpit is:—

$$\frac{\text{weight of clinker (Item 12A) + weight of ash (Item 13A)}}{\text{total weight of dry coal (Item 5 B)}} \times 100$$

$$= \frac{100 + 52}{2874} \times 100 = 5 \cdot 6$$

As just explained, this is less than Item 7A, on account of loss of ash.

Item 8B.—Total weight of combustible consumed.

This is evidently:—

$$\text{Total weight of dry coal (Item 5 B)} \times \frac{(100 - \text{Item 7A})}{100} = 2874 \times \frac{93 \cdot 1}{100}$$

2676 lbs.

Item 10B.—Equivalent water evaporated into dry steam, from actual feed water temperature, and at boiler pressure (pounds).

The feed water pumped into the boiler was not all actually evaporated, since steam withdrawn from the steam drum of the boiler was found to contain unevaporated moisture. A correction must, therefore, be applied.

We have as data:—

Item 26A—Steam pressure in boiler by gauge, lb. per sq. in.	118·4
Item 27A—Barometric pressure per sq. in	14·5
Absolute steam pressure lb. per sq. in.	132·9
Latent heat of steam at this pressure (from steam tables) B.T.U.	867·5
Heat of the liquid from 32° (from tables)	320·8
Total heat of steam at 132·9	1188·3
Item 28A—Steam pressure in calorimeter by gauge, lb. per sq. in.	15·6
Barometric pressure, lb. per sq. in.	14·5
Absolute steam pressure lb. per sq. in.	30·1

Total heat of steam at this pressure (from steam tables) B.T.U.	1158·3
Temperature of saturated steam at 30·1 lb. per sq. in. (from tables) deg. F.	250·4
Item 29A—Actual temperature in calorimeter deg. F.	292·3
Superheat in calorimeter deg. F.	41·9

Now taking 0·6 as the specific heat of superheated steam we have: total heat of 1 pound steam at 30·1 pounds per square inch superheated 41·9° F. = 1158·3 + (0·6 × 41·9) = 1158·3 + 25·1 = 1183·4 B.T.U. This is the same as the total heat of one pound of wet steam before entering calorimeter, since no heat is lost or gained. Hence, if the steam is passed into the calorimeter without loss or gain of heat, and contained originally x per cent of moisture, we have

$$320\cdot8 + \frac{100 - x}{100} \times 867\cdot5 = 1183\cdot4.$$

from which $x = 0\cdot6$ per cent. (Table IV, Col. 27).

Item 21A.—Again, feed water temperature was 73·5° F. and, from steam tables, one pound of water requires 41·5 B.T.U. to warm it from 32° to 73·5°; hence,

Heat given to each pound of feed water at 73·5° to form one pound of wet steam of total heat 1183·4 B.T.U. = 1183·4 − 41·5 = 1141·9 B.T.U.

But if the boiler steam had been dry and saturated at a pressure of 132·9 pounds per square inch absolute, its total heat per pound would have been 1188·3 B.T.U. and the heat given to each pound of feed water would have been 1188·3 − 41·5 = 1146·8 B.T.U. Hence, the actual heat given to 17,691 pounds of feed water, converting them into steam still containing 0·6 per cent of moisture, would have completely evaporated, or turned into dry steam

$$17691 \times \frac{1141\cdot9}{1146\cdot8} = 17{,}620 \text{ pounds of feed water.}$$

This figure is, therefore, taken as the water actually evaporated corrected for moisture in steam.

Item 11B.—Equivalent water evaporated into dry steam from and at 212°.

From previous calculation the heat given to one pound of feed water at 73·5° and forming a pound of steam of the quality actually delivered by the boiler was found to be 1141·9 B.T.U. But if steam had been formed from water at 212° and at atmospheric pressure, the heat required per pound would have been 966 B.T.U.

The weight of dry steam evaporated from and at 212°, which would require the same expenditure of heat as the 17691 pounds of feed water actually fed to the boiler and converted into wet steam, is, therefore,

$$17691 \times \frac{1141\cdot9}{966} = 20920 \text{ lbs.}$$

Item 12B.—Dry coal fired per hour.

Item 5 B ÷ Item 2 B = 2874 ÷ 10 = 287·4 pounds.

Item 13B.—Dry coal per square foot of grate surface per hour.

Item 12 B ÷ 16·79 = 287·4 ÷ 16·79 = 17·1 pounds.

Item 14B.—Water evaporated per hour, corrected for quality of steam.

Item 10 B ÷ Item 2 B = 17620 ÷ 10 = 1762 pounds.

Item 15B.—Equivalent evaporation per hour from and at 212°.

Item 11 B ÷ Item 2 B = 20920 ÷ 10 = 2092 pounds.

Item 16B.—Equivalent evaporation per hour from and at 212° pe square foot of water heating surface.

Item 15 B ÷ 639 = 2092 ÷ 639 = 3·27 pounds.

The Items 17 to 20B require no explanation. The method of obtaini Item 21B (moisture in steam) has already been given (see under Item 10 The simple calculations for Items 25 to 28B are given on the sheet.

Item 29B.—Calorific value of dry coal per pound. This quantity wa determined in each case in a bomb calorimeter, and full details of the calori-metric tests will be found in Part IX of this Volume

Item 30B.—Calorific value of the combustible per pound.

Item 7A shows that 94·1 per cent of the dry coal fired was combustible, hence calorific value of one pound of combustible

$$\frac{100\times\text{calorific value of 1 lb. dry coal}}{94\cdot1} = \frac{100\times13860}{94\cdot1} = 14740 \text{ B.T.U.}$$

Item 31B.—Efficiency of boiler (based on combustible consumed).

This efficiency is the ratio of the heat actually used in warming an evaporating water, to the heat obtained from, and rendered available by, th furnace.

From Item 28 B for each pound of combustible consumed there w given to the water in the boiler an amount of heat equivalent to the evap tion of 7·83 pounds of water from and at 212°, hence

$$\text{Efficiency} = \frac{\text{Item 28B}\times966}{\text{Item 30B}} = \frac{7\cdot83\times966}{14740} = 51\cdot4 \text{ per cent.}$$

Item 32B.—Efficiency of boiler including grate (based on dry coal

This efficiency is the ratio of the heat actually used in warming a evaporating water, to the heat which would be obtained by the perfect c bustion of the coal fired, allowing for the moisture present in the coal.

From Item 27 B an amount of heat equivalent to the evaporatio 7·27 pounds of water from and at 212° was obtained from the combusti each pound of dry coal and utilized, hence

$$\text{Efficiency} = \frac{\text{Item 27B}\times966}{\text{Item 29B}} = \frac{7\cdot27\times966}{13860} = 50\cdot6 \text{ per cent.}$$

Item 33B.—Dry flue gas per pound of carbon (from gas analyses).

Item 20A gives the gas analyses by volume. The relative weights of the constituent gases referred to hydrogen as unity are taken as

Carbon dioxide.	22
Oxygen.	16
Carbon monoxide	14
Nitrogen, etc.	14

Thus the weight of 100 volumes of flue gas, containing n_1 volumes of carbon dioxide, n_2 volumes of oxygen, n_3 of carbon monoxide, and n_4 of nitrogen and other residual gases, would be given by the expression

$$\frac{22n_1 + 16n_2 + 14(n_3 + n_4)}{100}$$

if referred to the weight of 100 volumes of hydrogen.

Now carbon dioxide contains $\frac{3}{11}$ of its weight of carbon, and carbon monoxide contains $\frac{3}{7}$ of its weight of carbon, so that the weight of carbon in 100 volumes of flue gas will be

$$\frac{22n_1 \times \frac{12}{44} + 14n_3 \times \frac{12}{28}}{100} = \frac{6(n_1 + n_3)}{100}$$

times the weight of 100 volumes of hydrogen. Hence, the weight of flue gas containing one pound of carbon will be

$$\frac{\text{weight of 100 vols. flue gas}}{\text{weight of carbon in 100 vols. flue gas}} = \frac{22n_1 + 16n_2 + 14(n_3 + n_4)}{6(n_1 + n_3)}$$

$$= \frac{11n_1 + 8n_2 + 7(n_3 + n_4)}{3(n_1 + n_3)} \text{ pounds}$$

Here $n_1 = 9{\cdot}8$; $n_2 = 8{\cdot}2$; $n_3 = 1{\cdot}2$; $n_4 = 80{\cdot}8$ and

$$\text{Item 33B} = \frac{(11 \times 9{\cdot}8) + (8 \times 8{\cdot}2) + 7(1{\cdot}2 + 80{\cdot}8)}{3(1{\cdot}2 + 9{\cdot}8)} = \frac{747{\cdot}4}{33} = 22{\cdot}6 \text{ pounds}$$

Item 34B.—Dry flue gas per pound of combustible consumed.

$$\text{This is given by} \quad \text{Item 33B} \times \frac{\text{Total dry coal used}}{\text{Total combustible consumed.}}$$

$$= \text{Item 35} \times \frac{\text{Item 5B}}{\text{Item 8B}} = 17{\cdot}3 \times \frac{2874}{2676}$$

$$= 18{\cdot}6 \text{ pounds.}$$

Item 35B.—Dry flue gas per pound of dry coal.

This is given by Item 33B × carbon per pound of dry coal

$$= \text{Item 33} \times \frac{\text{Item 7A}}{100}$$

$$= 22{\cdot}6 \times 0{\cdot}767 = 17{\cdot}3 \text{ pounds.}$$

Item 36B.—Proportion of heat of fuel in escaping dry flue gases.

This is the ratio of the heat carried away by the flue gases, to the heat which would be developed by the complete combustion of the amount of dry coal fired.

The air entering the furnace and combining with the fuel leaves the boiler at the temperature given by Item 19A, the entering temperature being given by Item 18A. Neglecting the difference between the weight of air enterin and the weight of flue gas leaving the boiler, and taking 0·24 as the mea specific heat of the gas, each pound of flue gas carries away

$$0{\cdot}24\ (\text{Item 19A} - \text{Item 18A})\ \text{B.T.U.}$$

Therefore, for each pound of dry coal the heat carried away is

$$\text{Item 35B} \times 0{\cdot}24 \times (\text{Item 19A} - \text{Item 18A})$$

$$= 17{\cdot}3 \times 0{\cdot}24\ (616 - 90{\cdot}5) = 2180\ \text{B.T.U.}$$

Expressed as a proportion of the heat value of a pound of dry coal (Item 29B or 8A) this becomes $\frac{2180}{13860} \times 100 = 15{\cdot}7$ per cent.

REMARKS ON BOILER TRIALS AND THEIR RESULTS

VALUE OF COAL

The actual worth of a given fuel for steam purposes, as has been already pointed out, depends primarily on the amount of heat which can be utilized in the boiler as the result of a given expenditure for fuel, and, secondarily, on the labour and maintenance costs resulting from the use of that fuel. In testing a series of coals it is thus impossible to state definitely their actual or even relative values for steam purposes, unless complete information as to cost of fuel and labour is available, and in the present instance all that can be done is to discuss the leading characteristics of the coals tested, regardless of cost, but taking into consideration the evaporative power and the operating conditions found in working with each coal.

The figures on which the following notes are based will be found in Table IV (Summary Record of Boiler Tests), and it will be observed that the coals are there arranged in geographical order. The Sydney coals are given first, followed by the coals from Inverness and Pictou counties, Nova Scotia, from the Springhill and Joggins coal fields in Nova Scotia, and from the Grand Lake coal field in New Brunswick. The next group is from the west, and includes the bituminous coals, lignites, and lignitic coals of Saskatchewan and Alberta; the Crowsnest coals of British Columbia follow, and next in order are the coals from the Cascade coal field, Alberta; the series is concluded by the remaining British Columbia coals, including those from Vancouver island. Samples from the Yukon could not be included in the series of boiler trials as a sufficient quantity of coal was not available.

COMPOSITION OF COALS

In the samples on which boiler trials were made, the proportion of ash varied from 2·7 per cent, in a washed Cape Breton coal, to 19·8 per cent in one of the Alberta coals. Volatile matter ranged from 12·5, in a washed coal from the Cascade coal field, up to 49 per cent, in one of the Saskatchewan lignites. The proportion of fixed carbon was from 42·9 per cent in the coal just mentioned to 78·6 in a washed coal from the Cascade coal field. The moisture content was naturally least (0·6 per cent) in one of the anthracite coals and largest (29·7 per cent) in one of the lignites. It is probable that

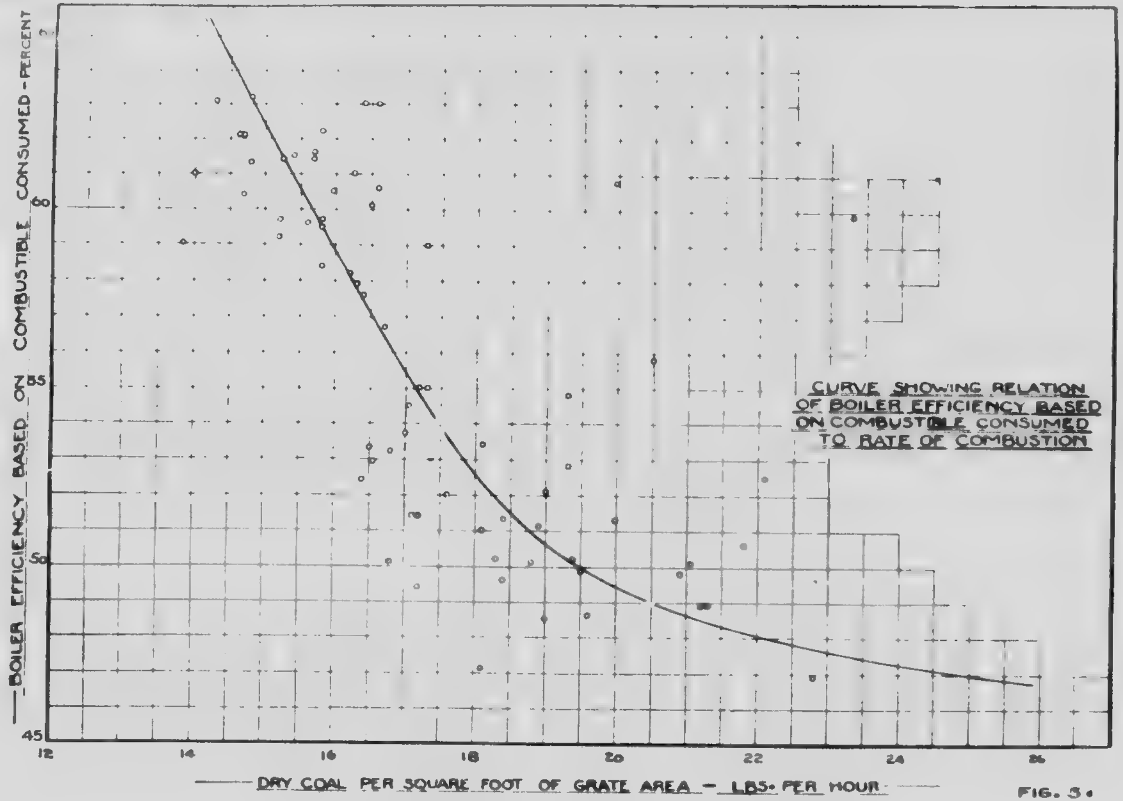

FIG. 3.

Fig. 35. Diagram showing boiler efficiency and rate of combustion.

the lignites when freshly mined contained even more moisture than is shown in Table IV, a certain amount having been inevitably lost in handling and transportation.

The calorific value will be seen to have had a fairly wide range, that of the dry coal varying from 10,690 to 14,390 B.T.U. per pound, while the calorific value of coal as fired varied from 7,520 to 14,010 B.T.U. per pound.

CONDITION OF COALS WHEN TESTED

The notes in Column 5, Table IV, give some information as to the treatment of the various coals at the colliery, but further details will be found in Part III, Vol. I, of this report. Their treatment after delivery at the University is described in detail in Part IV, Vol. I; but, speaking generally, it may be said that the coal as fired differed only from that delivered in that all lumps were broken to pass through a 3" ring. None of the smalls was removed from the coal, nor was it screened after passing through the crusher. For this reason comparatively small (¼") openings between the grate bars were adopted, and, as mentioned elsewhere, in certain trials even this was found too large.

Certain coals (Nos. 23 and 23 SP) were sized at the colliery and were not crushed further after delivery. The briquettes also were fired in exactly the condition in which they were delivered. All of the washed coals when fired were of a fairly uniform, small size; the unwashed bituminous coals and lignites were practically run of mine but with no lumps larger than 3".

GENERAL RESULTS.

With regard to the general results of the boiler tests, it may be noted that the rate of working the boiler, as shown by the equivalent evaporation per square foot of heating surface per hour, was as uniform as could be reasonably expected in such a series of trials; this figure ranged between 2·90 and 3·52 pounds. The lower values of this quantity in general correspond to cases in which the fire was dirty or hard to work, the higher figures to cases where a freer combustion could be used with more satisfactory results. The pressure of draft and the rate of combustion were, of course, varied as little as possible throughout the series, but necessary changes were made for each trial with a view to securing the best possible gas analysis, and their amounts are indicated by the figures representing the weight of dry coal fired per square foot of grate per hour, the minimum for which is 13·8 pounds with a coal of excellent quality, while the maximum is 23·3 pounds in the case of one of the lignites.

The better coals naturally required the lower rates of combustion, and as a rule gave the higher boiler efficiencies. This is well shown by the curve plotted in Fig. 35 (Boiler efficiency based on combustible[1] plotted against dry coal per square foot of grate per hour). In this figure it will be seen that with the exception of four coals which gave apparently an extraordinarily high boiler efficiency, the values fall fairly well around the mean curve. Th exceptions are, in fact, the points corresponding to the samples 10, 12, 13, an 14, lignites carrying much moisture, which age rapidly. It seems probabl that some change in the quality of these coals, occurring during the time whic unavoidably elapsed between the sampling, chemical analysis, and calori meter determinations, and the boiler trials, affords an explanation of th apparently high boiler efficiencies obtained with them. The equivalen evaporation per pound of coal as fired does not appear to be abnormally hig with these coals, which tends to confirm the above view.

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[1] *i.e.*, Efficiency of boiler only, excluding furnace.

It is well known that coals high in fixed carbon are, in general, utiliz more efficiently in boiler work than is possible with coals high in volat matter and low in fixed carbon. Fig. 36 illustrates this by showing the relatio (for the particular boiler and rate of working employed in these trials) betwe the boiler efficiency based on combustible (and therefore excluding grate) a the fixed carbon content of the combustible portion of the fuel. Here, agai the fuels 10, 12, and 13 appear to give somewhat abnormal results, and th boiler efficiencies as plotted are probably higher than the true values fo these coals.

The curves of Figs. 35 and 36 have been used in discussing the val of the various coals[1] and as a means of estimating the excellence or otherwis the combustion in each case, their indications being considered together w those of columns 38 and 40, Table IV. (Flue gas per pound of coal and gas temperature) for this purpose.

A general comparison of all the coals is rendered easy by the two diagrams of Fig. 37, which are self explanatory. In studying these diagrams, it should be borne in mind that higher evaporative efficiencies could, of course, be obtained in a larger and more efficient boiler plant.[2]

RELATIVE MERIT OF THE COALS.

In working out the results of these trials several attempts have made to determine an index number or figure for each coal, representin steam-raising value as compared with that of some well known standard A great objection to the inclusion of such figures in the summary of result however, that they would necessarily be calculated without reference to price of coal to the consumer, or the cost of its transportation, and would, ther fore, be misleading to the layman although perhaps instructive to the engine who could apply the necessary corrections and modifications. Actual course, a coal (A) having an index number of say 40 might be a more eco ical fuel than one (B) whose number was 60, if the price of A as delivered w less than ⅔ that of B. It was, therefore, felt that it would be better to le figures of the boiler trials, as summarized in Table IV, speak for thems and only give such index numbers in discussing the various groups of coals

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[1] See pp. 34 to 39.

[2] See also p. 11.

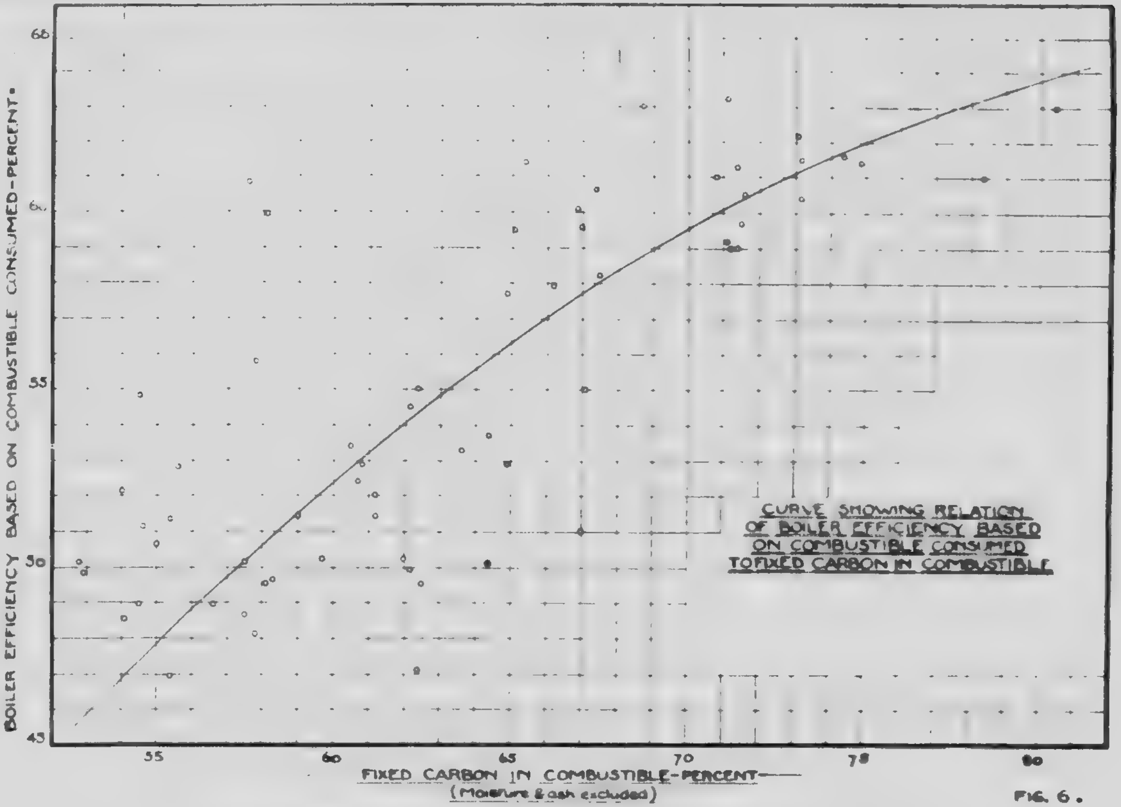

FIG. 6.

Fig. 36. Diagram showing boiler efficiency and percentage of fixed carbon.

The method of arriving at an index number which was finally adopted was worked out in the following way:—

The economic value of a steam coal, apart from its cost, was taken as depending on:—

(a) The amount of steam obtained from a given weight of the fuel as fired. This evidently takes account of the effect of the combustible properties of the coal on the boiler efficiency, and also allows for the amount and value of the combustible part of the coal, and for the heat losses due to the high temperature of the flue gases, or due to cleaning fires, removal of ash, and evaporation of moisture in coal. The expense of handling coal in the boiler room for a given production of steam will evidently be least where the evaporation per pound of coal is highest and is, therefore, also taken account of.

(b) The expense of labour for handling ash and refuse will be greatest in clinkering coals producing much refuse which will not pass through the grate. Two coals of equal evaporative power per pound may evidently be of unequal economic value from this cause. The total amount of incombustible matter having been taken account of under (a), a figure based on the ratio $\frac{\text{weight of ash}}{\text{weight of ash and clinker}}$ would give an idea of the non-clinkering quality of the fuel. The value of this factor, however, should obviously be small as compared with that of (a). Its numerical amount would be highest in a coal forming little or no clinker and in which all or nearly all the refuse could be removed by the use of a shaking grate.

In working out this idea, factor (a) received a value of 95 per cent and factor (b) 5 per cent, these figures indicating their relative importance, as judged by the following considerations:—

If the cost of labour in hand fired boiler plants is taken at one-fifth the cost of the fuel itself, and if we assume that about one-fourth of the total labour cost is due to cleaning fires and handling ashes, it would appear that to the factor (b) should be assigned about one-twentieth of the weight given to factor (a), and this has accordingly been done. These figures are, however, somewhat arbitrary ones, and the resulting "index numbers" should be taken for what they are worth. Their chief use should be, to compare various coals of the same group, and in particular to illustrate the effect of washing coals more clearly than can be done by simply comparing the equivalent evaporation per pound of coal, washed and unwashed.

In selecting a standard fuel on which to base these index numbers two kinds of coal naturally present themselves. The first is a Welsh coal of first quality, such as Nixon's Navigation, containing about 3 per cent of ash and having a calorific value of about 15,500 B.T.U. per pound of dry coal, which might be chosen, and given a rating of 100. A series of very careful boiler trials made in England with this coal[1] shew a mean value of the

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[1] Donkin and Kennedy. Experiments on steam boilers—London, 1897. Offices of "Engineering."

$\frac{\text{ash}}{\text{ash and clinker}}$ of about 0·65, and in boilers of about the same efficiency as the Babcock and Wilcox boiler used in the trials here reported, gav an equivalent evaporation (per pound of coal as fired) of about 10·0 pound

A high class Welsh coal, however, though widely known, is not easil available in Canada, and its qualities are not so familiar to Canadian pow users as those of certain American coals, whose use has become standard boiler trials in the United States. Such coals are Pocahontas and Georg Creek, from the Maryland and West Virginia coal fields. Trials have bee made from time to time in the McGill University experimental boiler plan with the last named of these, and for comparison three additional te were made on No. 2 Babcock and Wilcox boiler during the progress of th series here reported on, with Georges Creek coal purchased in Montre This coal, as placed on the Canadian market, appears to vary somewhat quality, and the leading results of the three tests are as given below:—

TABLE V

Trials of Georges Creek Coal on No. 2 B. and W. Boiler.

Trial No.	Date	Calorific value per lb. as fired. B.T.U.	Coal as fired per sq. ft. grate per hr. lbs.	Equiv. evap. per lb. as fired. lbs.	Ash. lbs.	Clinker. lbs.	Refuse as weighed %	Moisture in coal as fired. %	Boiler efficiency dry coal
1	20-6-07	13810	14·25	8·53	85	136	9·3	1·9	59·6
68	21-9-09	13060	15·07	8·28	77	275	14·2	2·9	61·
72	15-4-10	13510	14·45	8·91	104	177	11·8	2·0	63·6
			Average	8·57	88	196			

This coal, as compared with Nixon's Navigation, would appear to h an index number of about 83·8, the method of calculation being as follow

Coal. Georges Creek as purchased in Montreal.

Trials Nos. 1, 68, and 72.

Average equivalent evaporation per pound of coal as fired, 8·57 lbs.

Average weight of ash, 88 lbs.

" " clinker, 196 lbs.

$$\text{Ratio } \frac{\text{ash}}{\text{ash + clinker}} = \frac{88}{284} = 0{\cdot}31$$

For the Welsh coal, the figures are:

(a) Average equivalent evaporation per pound of coal as fired 10·0 lbs. ....Value 5

(b) Average ratio = $\frac{\text{ash}}{\text{ash + clinker}}$ = 0·65 ....Value 5

Hence for Georges Creek the index number as compared with the above would be: –

$$\text{(a) } 8{\cdot}57\times\frac{95}{10} = 8{\cdot}57\times9{\cdot}5 = 81{\cdot}4$$

$$\text{(b) } 0{\cdot}31\times\frac{5}{0{\cdot}65} = 0{\cdot}31\times7{\cdot}7 = 2{\cdot}4$$

$$\text{Total } 83{\cdot}8$$

and for any given coal, the figure as compared with Welsh would be
(equivalent evaporation × 9·5 + ash ratio × 7·7) per cent
or, if compared with Georges Creek,
(equivalent evaporation × 11·3 + ash ratio × 9·2) per cent.

The effect of the term (b) is well shown on comparing, for instance, coals 42 and 43, in which we have

Coal No.	Trial No.	Equiv. Evap.	Ash lbs.	Clinker lbs.	Ash Ratio
42	65	4·98	265	115	0·70
43	64	4·91	119	556	0·18

As compared with the Welsh coal we should have the following rating:—

No. 42 = 4·98 × 9·5 + 0·70 × 7·7 = 47·3 + 5·4 = 52·7%,
No. 43 = 4·91 × 9·5 + 0·18 × 7·7 = 46·6 + 1·4 = 48·0%,

and, as compared with Georges Creek, the values would be:

No. 42 = 4·98 × 11·3 + 0·70 × 9·2 = 56·3 + 6·4 = 62·7%,
No. 43 = 4·91 × 11·3 + 0·18 × 9·2 = 55·5 + 1·7 = 57·2%,

Nos. 42 and 43 are lignites carrying a high percentage of ash and refuse, but 42 proved considerably easier to work than 43, the benefit being obviously greater than would be shown by merely comparing the figures for equivalent evaporation

The reader will find the index numbers for each group of coals in the remarks and tables following.

In selecting a coal for steam power purposes, the purchaser should be guided (1) by the comparison of the costs of the various coals as delivered to his boiler room, (2) by the comparative evaporative efficiencies, and, (3) by the difficulties arising in working the fire and handling refuse as shown by trial logs and results. The cost of ash disposal is often an important factor, but in cases where refuse has not to be carted away, the amount of ash and refuse produced needs comparatively little consideration. Again, circumstances may be such that the emission of smoke cannot be permitted; in other cases, production of smoke causes no trouble. Such factors as these must be considered separately in each case.

The following is a list of the coals tested in order of evaporative efficiency, *i.e.*, equivalent evaporation from and at 212° per pound of coal as fired:—

TABLE VI

Coals in Order of Evaporation

(Equivalent evaporation per pound of coal as fired.)

Coal No.	Location	Equiv. Evap.
27	No. 2 mine, Coal Creek, Fernie, B.C.	8·66
8 (Trial 11)	Main seam, Acadia colliery, Westville, N.S.	8·55
225	Washed, Old mine, Canmore, Alta.	8·44
26	No. 5 mine, Coal Creek, Fernie, B.C.	8·25
8 (Trial 32)	Main seam, Acadia colliery, Westville, N.S.	8·25
29	No. 9 mine, Michel, B.C.	8·24
223 M	Washed, Bankhead colliery, Bankhead, Alta.	8·20
231	Washed, No. 3 mine, Michel, B.C.	8·16
30	No. 7 mine, Michel, B.C.	8·11
31	No. 3 mine, Michel, B.C.	8·08
300	Washed, Main seam, Drummond colliery, Westville, N.S.	8·07
51	No. 2 seam, Hosmer, B.C.	7·84
232	Washed, Hillcrest colliery, Hillcrest, Alta.	7·77
25	Old mine, Canmore, Alta.	7·74
3 (Trial 3)	Main seam, Drummond colliery, Westville, N.S.	7·69
221 M	Washed, Comox colliery, Cumberland, B.C.	7·68
32	Hillcrest colliery, Hillcrest, Alta.	7·65
234	Washed, Denison colliery, Coleman, Alta.	7·60
52	No. 6 seam, Hosmer, B.C.	7·57
3 (Trial 7)	Main seam, Drummond colliery, Westville, N.S.	7·53
2	Cage Pit seam, Albion colliery, Stellarton, N.S.	7·49
21 M	Comox colliery, Cumberland, B.C.	7·41
33	No. 1 seam, Bellevue colliery, Lille, Alta.	7·41
233	Washed, No. 1 seam, Bellevue colliery, Lille, Alta.	7·40
38	Phalen seam, Glace Bay, N.S.	7·40
1	3rd seam, Albion colliery, Stellarton, N.S.	7·38
1001	" " " "	7·38
205	Washed, No. 2 colliery, Springhill, N.S.	7·36
236	Washed, Hub seam, Glace Bay, N.S.	7·35
23 M	Bankhead colliery, Bankhead, Alta.	7·30
24	(Briquettes), Bankhead, Alta.	7·27
16	Foord seam, Allan shaft, Stellarton, N.S.	7·22
35	Harbour seam, Glace Bay, N.S.	7·21
206	Washed, No. 3 colliery, Springhill, N.S.	7·20
237	Washed, Emery seam, Glace Bay, N.S.	7·17
34	Denison colliery, Coleman, Alta.	7·17
36	Hub seam, Glace Bay, N.S.	7·08
213	Washed, No. 1 colliery, Sydney Mines, N.S.	7·01
37	Emery seam, Glace Bay, N.S.	6·90
211	Washed, King's mine, Minto, N.B.	6·81
12	No. 2 colliery, Sydney Mines, N.S.	6·77
20	Wellington seam, Cumberland, B.C.	6·76
13	No. 1 colliery, Sydney Mines, N.S.	6·74
5	No. 2 colliery, Springhill, N.S.	6·63
48	Leitch colliery, Passburg, Alta.	6·61
18	Upper seam, No. 1 mine, Nanaimo, B.C.	6·59
207	Washed, Chignecto colliery, Chignecto, N.S.	6·51
204	Washed, 6 ft. seam, Vale colliery, New Glasgow, N.S.	6·24
210	Washed, Joggins colliery, Joggins, N.S.	6·22
222 M	Washed, Middlesboro colliery, Coutlee, B.C.	6·22
6	No. 3 colliery, Springhill, N.S.	6·18

TABLE VI (*Continued.*)

Coal No.	Location.	Equiv. Evap.
17	Lower seam, No. 1 mine, Nanaimo, B.C.	6·17
22 M	Middlesboro colliery, Coutlee, B.C.	6·17
209	Washed, Minudie colliery, River Hebert, N.S.	6·09
4	6 ft. seam, Vale colliery, New Glasgow, N.S.	6·04
11	King's mine, Minto, N.B.	6·03
44	Galt colliery, Lethbridge, Alta.	5·92
Ex. 234	Pacific Coast Coal Co., Ltd., Vancouver island	5·92
215	Washed, Port Hood colliery, Port Hood, N.S.	5·85
7	Chignecto colliery, Chignecto, N.S.	5·82
214	Washed, Inverness colliery, Inverness, N.S.	5·67
15	Port Hood colliery, Port Hood, N.S.	5·67
10	Joggins colliery, Joggins, N.S.	5·66
9	Minudie colliery, River Hebert, N.S.	5·61
14	Inverness colliery, Chignecto, N.S.	5·46
42	Parkdale Coal Co., Edmonton, Alta.	4·98
43	Canada West Coal Co., Taber, Alta.	4·91
40	Western Dominion colliery, Taylorton, Sask.	3·91

TREATMENT AND BEHAVIOUR OF COAL IN FIRE

It is often the case that a coal of satisfactory calorific value and reasonably low in ash proves unsuitable as a boiler fuel on account of its behaviour in the fire, and such a coal by reason of the difficulty in working with it may be actually inferior as a practical fuel to another sample of lower evaporative efficiency. The trials here reported included almost every commercial variety of coal. Some were of excellent quality, and gave little trouble either as regards clinkering or smoke. Other samples were troublesome and dirty, requiring steam under the grate and a moderate forced draft to obtain the desired results.

Brief notes as to the treatment and behaviour of the coals will be found in one column in Table IV, and fuller information in the detailed logs of each trial published in Vol. IV, of this report.

For convenience in comparing the coals of each of the principal groups, tables[1] and notes are given below under the various geographical headings embodying the observations made during the trials as to smoke production, trouble from clinker, coking qualities of coal, and possibility of using a shaking grate. These, with information as to the frequency of slicing and cleaning the fire, will enable a judgment to be formed as to the quality of the coals from the fireman's point of view. It should be noted that in order to carry out the trials, it was necessary to clean the fire in every case just before the close of the test; this has, of course, been included in stating the number of times the fire was cleaned.

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[1] Tables VII, X, XV, XVII, XIX, XXI, XXIV, and remarks in text.

REMARKS ON COALS AS ARRANGED GEOGRAPHICALLY BY COAL FIELDS

SYDNEY COALFIELD, CAPE BRETON COUNTY, N. S.

Coals from mines of Dominion Coal Co., and Nova Scotia Steel & Co Co. (Nine boiler trials, six on unwashed samples.)

These are all bituminous coals, giving a long flame and considerab smoke. The equivalent evaporation per pound of dry coal ranged fro 6·91 to 7·68, and the steam raising value of the coals, as compared wit Welsh of high quality, is estimated at from 67 per cent to 74 per cent, from 79 per cent to 87 per cent as compared with Georges Creek. T average for the six unwashed coals is 83·2 per cent. Washing impro the evaporation from 5 to 6 per cent. Most of the samples were goo steam coals, although several gave trouble from clinker, the worst being tho from No. 1 colliery, N. S. S. & C. Co., and the Hub seam, D. C. Co. The fir named needed a slight air pressure under the bars; all the rest were bur with natural draft. The clinker from the Hub Seam coal was found to att the fire bars. Coals from the Hub and Phalen seams, D. C. Co., appeared give the best all round results.

TABLE VII.

Remarks on Combustion of Sydney Coals

Coal No.	36	236	35	38	37	237	13	213	[illegible]
Draft, natural or forced	N	N	N	N	N	N	N and F	N	[illegible]
Smoke . .	Much	Much	Much	Much	Dense	Much	Much	Much	[illegible]
Flame. . .	Much	Much	Long	Much	Much	Much	Much	Much	[illegible]
Fire sliced	3 times	twice	3 times	3 times	. . .	4 times	twice	once	[illegible]
Fire cleaned .	once	once	once	once	twice	once	twice	once	[illegible]
Clinker .	easy	hard attacks bars	some trouble	hard	easy	troublesome	some difficulty	easy	[illegible]
Steam under bar	no	yes	advisable	advisable	no	no	yes	yes	[illegible]
Does coal cake? .	no	good deal	no	slightly	slightly	very little	yes	yes	[illegible]
Could shaking grate be used	no	no	no	no	yes	no	no	. . .	[illegible]

TABLE VIII.

Evaporation with Sydney Coals.

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Equiv. evap. per lb. as fired
36	Hub seam, D.C. Co. . . .	13490	2·7	5·64	82·9	7·08
236	" " washed	13670	4·5	3·77	88·3	7·33
35	Harbour seam, D. C. Co. . .	13750	1·8	6·58	85·2	7·21
38	Phalen seam, D. C. Co. . .	13620	2·8	5·2	86·7	7·40
37	Emery seam, D. C. Co. . .	12750	2·8	9·8	80·6	6·90
237	" " " washed	13260	4·5	5·95	85·0	7·17
13	No. 1 colliery, N.S.S.& C. Co.	13450	2·3	5·9	79·8	6·74
213	" " " washed	14010	3·3	5·0	86·2	7·01
12	No. 2 colliery, N.S.S. & C. Co.	13110	4·2	7·1	79·4	6·77

INVERNESS COAL FIELD, INVERNESS COUNTY, N.S.

Coals from mines of Inverness Ry. & Coal Co. and Richmond Ry. Coal Co., Nova Scotia. (Four boiler trials, two on unwashed samples).

The two coals tested (each washed and unwashed) are bituminous coals somewhat high in ash, and gave an equivalent evaporation per pound of dry coal of from 5·86 to 6·24. The steam raising value of the unwashed coals, as compared with Georges Creek, would be from 66 per cent to 67 per cent. Washing increased the evaporation considerably and improved the index number to 70·0 per cent. Boiler efficiencies with these coals were somewhat low. Natural draft was used, with steam under the grate. The Port Hood coal seems the better of the two.

The unwashed coals were somewhat dirty in the fire, which was cleaned twice in each trial, and the use of the slice was also necessary. Shaking grates could not have been used. All four samples produced a fair amount of smoke. Clinker was adherent in the unwashed coals, but gave much less trouble in the washed samples.

TABLE I

Evaporation with Inverness Coals

Coal No	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Equiv. evap. per lb. as fired
14	Inverness coll., I. R. & C. Co.	11260	7·3	8·6	65·7	5·46
214	" " " washed	11620	9·2	6·0	70·2	5·67
15	Port Hood coll., R.R.C. Co. . .	11380	3·3	12·2	66·8	5·67
215	" " " washed	11860	5·5	9·7	70·2	5·85

PICTOU COAL FIELD, PICTOU COUNTY, N. S.

Coals from mines of Acadia Coal Co., Ltd., and Intercolonial Coal Mining Co., Nova Scotia. (Twelve boiler trials, of which nine were on unwashed, and three on washed samples).

These are bituminous coals giving a long flame, and are slightly higher in ash and lower in volatile matter than the Sydney coals; the equivalent evaporation per pound of dry coal ranged from 6·23 to 8·66; most of the samples are good and some were found to be excellent steam coals. The best unwashed samples were worth from 96 to 99 per cent, the remainder from 70 to 89 per cent as compared with Georges Creek. All were burnt with natural draft, and no serious difficulty with clinker was experienced, although a considerable amount was formed in most cases. The beneficial effect of washing on these coals was not very marked. Fairly high boiler efficiencies were obtained. Coal No. 8 from the Main seam, Acadia colliery, gave on the whole the most satisfactory results. The samples of three of these coals were large enough to allow of two trials—coals Nos. 1, 3, and 8.

TABLE X.

Remarks on Combustion of Pictou County Coals

Coal No.	4	204	16	1	1001
Draft, natural or forced	N	N	N	N	N
Smoke	....	....	....	much	much
Flame		much	much	much	...
Fire sliced	......	......	......	3 times	once
Fire cleaned	twice	twice	twice	once	twice
Clinker	not much trouble	some trouble	troublesome	easy	easy
Steam under bars	no	no	no	no	no
Does coal cake?	....	no	yes	yes	yes
Could shaking grate be used?		....	....	yes	yes

TABLE X.—(*Continued*)

Coal No.	2	8 (Trial 11)	8 (Trial 32)	3 (Trial 3)	3 (Trial 7)	20
Draft, natural or forced	N	N	N	N	N	N
Smoke	....	....	light	.	...	
Flame	much	much	much	.		
Fire sliced	....	....	....	7 times	3 times	3 times
Fire cleaned	twice	once	..	twice	3 times	once
Clinker	easy	some trouble	easy	some trouble	little trouble	easy
Steam under bars	....	....	no	....		
Does coal cake?	no		no			yes
Could shaking grate be used?			yes			..

NOTE.—A boiler trial (No. 18) was made with No. 1 coal after washing, but, on account of an error in sampling, the test had to be rejected, and is, therefore, not published.

TABLE XI

Evaporation with Pictou County Coals

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Equiv. evap. per lb. as fired
4	Vale colliery, A. C. Co.	11680	2·8	14·3	69·6	6·04
204	" " " washed	12260	3·9	10·3	72·5	6·24
16	Allan Shaft colliery, A.C. Co. .	12990	1·8	9·9	84·5	7·24
1	3rd seam, Albion colliery, A. C. Co.	12330	2·0	10·8	85·9	7·38
1004	" " "	12210	2·0	12·7	86·2	7·38
2	Cage Pit seam, Albion colliery, A. C. Co.	12880	2·3	11·6	87·2	7·49
8	Main seam, Acadia colliery, A.C. Co..	13640	1·6	8·2	98·8	8·55
8	Main seam, Acadia colliery, A.C. Co	13660	1·5	8·37	95·8	8·25
3	Drummond colliery, I.C.M. Co.	12820	1·1	12·4	89·2	7·69
3	" " " .	12810	1·2	12·6	87·6	7·53
203	" " " washed	13320	1·7	9·03	94·3	8·07

SPRINGHILL COAL FIELD, CUMBERLAND COUNTY, N.S.

From mines of Cumberland Railway & Coal Co., Ltd., Nova Scotia. (Four boiler trials, two on unwashed and two on washed samples.)

These are bituminous coals of moderately good steaming quality, not very high in ash and giving considerable smoke. Both were burnt under natural draft, giving an equivalent evaporation per pound of dry coal of from 6·13 to 7·63. Clinker was viscous in all four trials. The No. 2 Colliery coal gave the best evaporation, while that from No. 3 gave least trouble in working the fire. As compared with Georges Creek, these coals appear to have a value of 71 per cent to 77 per cent, which is increased very considerably on washing.

TABLE XII

Evaporation with Springhill Coals

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Equiv. evap. per lb. as fired
5	No. 2 colliery, C. R. & C. Co.	13120	1·9	7·9	76·7	6·63
205	" " " washed	13330	3·8	5·6	86·0	7·36
6	No. 3 colliery, C. R. & C. Co.	12710	2·2	8·8	71·4	6·18
206	" " " washed	13110	3·4	8·1	85·3	7·20

JOGGINS-CHIGNECTO COAL FIELD, CUMBERLAND COUNTY, N.S.

From mines of Maritime Coal, Ry. & Power Co., Minudie Coal Co., Ltd. and Canada Coal & Ry. Co., Ltd., Nova Scotia. (Six boiler trials, three on unwashed and three on washed samples.)

These are bituminous coals of moderate steaming quality, fairly high in ash, and giving some trouble in working the fire, but are better boiler fuel after washing. Steam under the bars was found necessary, except for No. 210, and forced draft was needed in three of the tests. The equivalent evaporation per pound of dry coal in this group was from 5·78 to 6·67. The washed coal from the Joggins mine gave the least trouble from clinker, although the Chignecto coal gave the best evaporation and boiler efficiency. These coals in the unwashed state appear to have from 65 per cent to 70 per cent of the steaming value of Georges Creek coal.

TABLE XIII

Evaporation with Joggins-Chignecto Coals

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Equi evap per l as fire
7	Chignecto colliery, M.C.R. & P. Co.	11790	3·0	11·2	70·4	5·82
207	Chignecto colliery, M.C.R. & P. Co.	12210	5·3	7·3	75·9	6·51
9	Minudie colliery, M. C. Co.	11500	2·8	12·2	65·4	5·61
209	" " " washed	12160	3·5	12·7	71·4	6·09
10	Joggins colliery, C. C. & R. Co.	11250	2·9	14·8	66·2	[illegible]
210	" " " washed	12250	3·8	8·2	73·7	6·22

GRAND LAKE COAL FIELD.

Coal from King's mine, Minto, N.B. (Two Boiler Trials.)

A bituminous coal carrying a fair amount of ash and of moderate steaming quality. Considerably improved by washing. The unwashed coal required forced draft, and steam under the bars; fire had to be cleaned three times, as clinker was rather troublesome. Boiler efficiency was rather low.

TABLE XIV

Evaporation with Grand Lake Coal

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No	Equi evap per as fire
11	King's mine, Minto, N.B.	12800	0·7	11·3	70·6	6·03
211	" " " washed	13590	1·7	9·4	79·3	6·80

SOURIS, EDMONTON, AND BELLY RIVER COAL FIELDS.

Lignites and Lignitic Coals from Saskatchewan and Alberta.

Mined by the Western Dominion Collieries Ltd., Taylorton, Sask., Parkdale Coal Co., Edmonton, Alta., Canada West Coal Co., Taber, Alta., and the Alberta Ry. & Irrigation Co., Ltd., Lethbridge, Alta. (Four boiler trials, all on unwashed samples.)

These very interesting fuels, of low calorific value, are moderately high in ash, and contain much moisture. They weather rapidly on exposure to air, and as some time necessarily elapsed after receipt before they could be tested, the results of the trials can not apply with exactness to freshly mined coal. The tests with No. 14 and No. 10 were unavoidably short, owing to the small amount of fuel available. The unexpectedly high boiler efficiencies apparently obtained may be due to the fact that the real calorific values of the coals when used differed from those found by the chemists at an earlier date. The following table gives an idea of the working qualities of these fuels.

TABLE XV

Remarks on Combustion of Lignites and Lignitic Coals

Coal No.	10	12	13	14
Draft, natural or forced.	F	N	N and F	F
Smoke	very little	none	light	none
Flame	long	..	long	
Fire sliced.	4 times	4 times	once	twice
Clinker.	easy	bad	moderate	bad without steam
Fire cleaned	once	twice	twice	once
Steam under bars	no	yes	yes	yes
Does coal cake?	no	no	no	no
Can a shaking grate be used?	yes	yes, with steam	yes, with steam	no

The steaming value of these fuels is estimated at from 18 per cent to 68 per cent of that of Georges Creek coal. Owing to the amount of moisture inseparable from these coals, the evaporation per pound of dry coal is not a satisfactory criterion.

TABLE XVI

Evaporation with Lignites and Lignitic Coals

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Equiv. evap. per lb. as fired
10	Western Dom. Colliery Co., Taylorton, Sask.	7520	29·7	8·24	18·4	3·91
12	Parkdale Coal Co., Edmonton, Alta.	8760	19·7	11·4	62·7	4·98
13	Canada West Coal Co., Taber, Alta.	9790	11·3	17·3	57·2	4·91
14	Galt colliery, Lethbridge, Alta.	10740	8·3	10·4	68·7	5·92

FRANK-BLAIRMORE COAL FIELD, ALBERTA.

Coals mined by Leitch Collieries Ltd., Hillcrest Coal and Coke Co., Lt
West Canadian Collieries Co., and International Coal and Coke Co., L
(Seven boiler trials, four on unwashed and three on washed samples.)

These are bituminous coals not very high in volatile matter, but carryi a considerable amount of ash. They are nevertheless good steam co giving little trouble in working the fire. They gave good boiler efficienci and the equivalent evaporation per pound of dry coal ranged from 6·67 to 7·69 for the unwashed samples.

The following table gives the working qualities of the coals from the Fra Blairmore coal field:

TABLE XVII

Remarks on Combustion of Frank-Blairmore Coals

Coal No.	48	32	232
Draft, natural or forced..	F and N	N	N
Smoke .	moderate	rather heavy	not much
Flame	moderate	moderate	moderate
Fire sliced	.	raked	....
Fire cleaned . .	twice	twice	twice
Clinker .	. .	little trouble	little trouble
Steam under bars,	no	no	no
Does coal cake? .	considerably	yes	slightly
Could shaking grate be used?.	yes	yes	yes

TABLE XVII (*Continued*)

Coal No.	33	233	34	234
Draft, natural or forced	F	F	F	F
Smoke.	dense	fairly dense	fairly dense	fai den
Flame .	moderate	moderate	moderate	mode
Fire sliced . .	. . . .	raked	raked	
Fire cleaned	twice	once	twice	twi
Clinker. . . .	little trouble	hardly any	easy	not m troub
Steam under bars . .	–			
Does coal cake? . . .	somewhat	somewhat	yes	slightly
Could shaking grate be used? . . .	yes	yes	yes	yes

Washing appears of somewhat doubtful value if these coals are intended for steam purposes. The index numbers indicate that the unwashed coals have from 76 per cent to 89 per cent of the value of Georges Creek. No. 48 is the least satisfactory coal but is not so smoky as the others.

TABLE XVIII

Evaporation with Frank-Blairmore Coals

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Equiv. evap. per lb. as fired
48	Leitch colliery, Passburg, Alta.	12130	0·9	17·0	76·4	6·61
32	Hillcrest colliery, Hillcrest Alta. ..	12360	0·8	15·5	89·3	7·63
232	Hillcrest colliery, Hillcrest, Alta., washed.	12900	3·8	9·5	91·3	7·77
33	Bellevue colliery, Bellevue, Alta.. ..	12280	0·8	14·1	85·8	7·41
233	Bellevue colliery, Bellevue, Alta., washed.	12510	3·6	10·5	86·4	7·40
34	No. 2 seam, Denison colliery, Coleman, Alta. ..	11630	0·8	18·8	83·3	7·17
234	No. 2 seam, Denison colliery, Coleman, Alta., washed.	12690	3·7	10·6	89·8	7·60

CROWSNEST COAL FIELD

Coals mined by Crowsnest Pass Coal Co., Ltd., and Hosmer Mines Ltd., British Columbia. (Eight boiler trials, one only on a washed coal.)

These bituminous coals are somewhat low in volatile matter (21 per cent to 26 per cent) and carry a moderate amount of ash. They rank among the best Canadian steam coals and gave equivalent evaporations per pound of dry coal ranging from 7·68 to 8·75. As compared with Georges Creek their steaming values are estimated at 88 per cent to 101 per cent. Nearly all were burnt with natural draft and gave only a moderate amount of smoke. The most satisfactory all round were perhaps Nos. 26, 29, and 30, although 27 gave the highest evaporation.

TABLE XIX

Remarks on Combustion of Crowsnest Coals

Coal No.	31	231	30	29
Draft, natural or forced. . .	N	N	N	N
Smoke. . .	light	moderate	light	moderate
Flame . .	....	a good deal	....	considerable
Fire sliced . .	3 times	....	.	....
Fire cleaned .	once	twice	twice	twice
Clinker. . .	some trouble	hard	easy to handle	easy to handle
Steam under bars . . .	at times	no	no	no
Does coal cake? . . .	no	yes	very little	very slightly
Could shaking grate be used?. . .	yes, with steam	no	yes	yes

TABLE XIX (Continued).

Coal No.	31	[illegible]	[illegible]	9
[illegible] nature [illegible]	No, [illegible]	No, [illegible]	No	No
Smoke	fair amount	good deal	moderate	little
Flame	[illegible]	much [illegible]		
[illegible]			[illegible]	taken
Fire cleaned	once	twice	once	twice
Clinker	very little trouble	some trouble	some trouble	very little trouble
Steam under bar	yes	yes	No	Yes
Does coal cake?	slightly	No	little	no
Could shaking grate be used?	[illegible]	[illegible]	possibly	No

TABLE XX

Evaporation with Crowsnest Coals

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Eq. ev. per as f
31	No. 3 mine, Michel colliery C.N.P.C. Co.	13180	0.7	12.4	93.6	8.
231	No. 3 mine, Michel colliery C.N.P.C. Co., washed	13610	1.9	7.4	97.1	8.1
30	No. 7 mine Michel colliery C.N.P.C. Co.	13230	1.0	12.7	94.4	8.31
29	No. 8 mine, Michel colliery, C.N.P.C. Co.	13350	1.0	10.0	96.6	8.21
51	No. 2 seam, Hosmer mines	12570	1.1	15.3	90.2	7.8
52	No. 6 seam, " "	12890	1.5	16.2	87.8	[illegible]
27	No. 2 mine, Coal Creek, Fernie B.C., C.N.P.C. Co.	13680	1.0	9.6	101.3	8.6
26	No. 5 mine, Coal Creek, Fernie B.C., C.N.P.C. Co.	13350	1.0	10.8	95.7	8.2

CASCADE COAL FIELD.

Coals mined by H. W. McNeil Co., Canmore, Alta., and Bankhead M Ltd., Bankhead, Alta. (Five boiler trials, two on washed samples.)

These are anthracite coals containing 12 per cent to 17 per c volatile matter and (in the unwashed state) are rather high in ash. N 24 was a sample of briquettes made (with tar) from Bankhead anth dust. The briquettes did not seem much (if at all) superior in evapor efficiency to the plain coal. All the samples proved good steam coal w forced draft, and the unwashed samples gave equivalent evapo per pound of dry coal of 7·37 and 7·80. Boiler efficiencies were good, a the beneficial effect of washing was very marked.

TABLE XXX

Evaporation with Vancouver Island Coals

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Equiv. evap. per lb. as fired
[illegible]	Wellington seam, Wellington Extension colliery, W.C. Co. Ltd., Extension, B.C.	12980	1·4	6·3	79·4	6·76
18	Upper seam, No. 1 mine, W.F. Co., Ltd., Nanaimo, B.C.	12540	2·3	8·7	77·[illegible]	6·50
17	Lower seam, do.	12210	2·1	11·4	72·2	6·17
[illegible] M	No. 4 and 7 mines, Comox col. W.C. Co., Ltd., Cumberland, B.C.	12880	1·0	10·8	86·5	7·4[illegible]
221 M	Do. washed	13180	3·0	9·86	91·2	7·68
[illegible]	[illegible] mine, Merritt, [illegible] P.C.C. Co.	10050	5·3	15·86	68·4	5·02

[illegible] the Merritt B.C. coal [illegible] does not really belong [illegible]

TABLE XXI

Remarks on Combustion of Cascade Coals

Coal No.	25	225	23 M	223 M	24 (briquette)
Draft, natural or forced. . . .	F	F	F	F	F
Smoke. . .	none	none	none	practically none	very little
Flame . .	none	none	none	none	none
Fire sliced . .	3 times	3 times	twice	. .	3 times
Fire cleaned .	twice	once	twice	once	once
Clinker . . .	little trouble	not much trouble	very little and soft	very soft	soft lumps
Steam under bars . .	yes	yes	none	none	none
Does coal cake? . . .	no	no	no	no	no
Could shaking grate be used? . .	yes, with steam	yes, with steam	yes	yes	yes

No. 25 seems the better steam coal of the two, and would be worth about 91 per cent as compared with Georges Creek. No. 23 was easier to work in the fire.

TABLE XXII

Evaporation with Cascade Coals

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Equiv. evap. per lb. as fired
25	No. 1 mine, Canmore, Alta., H. W. McNeil Co. . . .	13400	0·8	15·6	90·6	7·74
225	No. 1 mine, Canmore, Alta. H. W. McNeil, washed .	13780	4·3	8·9	98·5	8·44
23 M	Mixed coal, Bankhead colliery Bankhead, Alta., B.M. Ltd.	13000	0·6	15·6	84·4	7·30
223 M	Mixed coal, Bankhead colliery, Bankhead, Alta., B.M. Ltd washed	13590	2·7	9·5	94·4	8·20
24	Briquettes from Bankhead colliery . .	13040	0·7	15·2	84·5	7·27

NICOLA VALLEY COAL FIELD, B.C.

Coal mined by the Nicola Valley Coal and Coke Co. (Two boiler trials, one on unwashed and one on washed coal).

The coal tried was a mixture from the Jewel seam, No. 1 mine, and the Rat Hole seam, No. 2 mine, Middlesboro colliery, Coutlee, B.C. It is a bituminous coal high in volatile matter and containing a fair amount of ash. It was burnt under natural draft, and gave a short flame and considerable smoke. It does not cake and could be worked on a shaking grate.

TABLE XXIII

Evaporation with Nicola Valley Coal

Coal No.	Description	Cal. value per lb. as fired	Moisture in coal as fired %	Ash and clinker from dry coal %	Index No.	Equi eva per l as fi
22 M	Mines 1 and 2, Middlesboro colliery, N.V.C.& C. Co	11160	4·8	11·0	72·1	6·1
222 M	Mines 1 and 2, Middlesboro colliery, N.V.C. & C. Co., washed . . .	11840	6·2	10·4	72·7	6·2

NANAIMO-COMOX AND ALERT BAY COAL FIELDS.

Coals mined by the Wellington Colliery Co., Ltd., at Extension a Cumberland, B.C., by the Pacific Coast Coal Co., Ltd., Alert bay, B.C and by the Western Fuel Co., Ltd., Nanaimo, B.C. (Six boiler trials, onl one on a washed sample.)

These are bituminous coals ranging from 10 per cent to 15 per cent i ash, and most are high in volatile matter. The Nanaimo-Comox coals a fairly good steam coals and may be classed as having from 72 per cent to per cent of the steaming value of Georges Creek. It was found impossi to avoid making considerable smoke. The Comox coal (No. 21 M) g the most satisfactory results in this group.

TABLE XXIV

Remarks on Combustion of Vancouver Island Coals

Coal No.	20	18	17	21 M	221 M	1
Draft, natural or forced . . .	N	N	N and F	N	N	N
Smoke . .	dense	medium	heavy	a large amount	medium	[illegible]
Flame. .	considerable	considerable	much	medium	medium	larg
Fire sliced. . . .	4 times	5 times	. . . .	raked	once and raked	[illegible]
Fire cleaned .	once	twice	twice	twice	twice	[illegible]
Clinker . . .	a good deal	troublesome	a good deal	much trouble	troublesome	[illegible]
Steam under bars.	no	yes	yes	no	yes	[illegible]
Does coal cake? .	no	no	slightly	slightly	yes	
Could shaking grate be used? . .	possibly	no	possibly with steam	yes	possibly with steam	

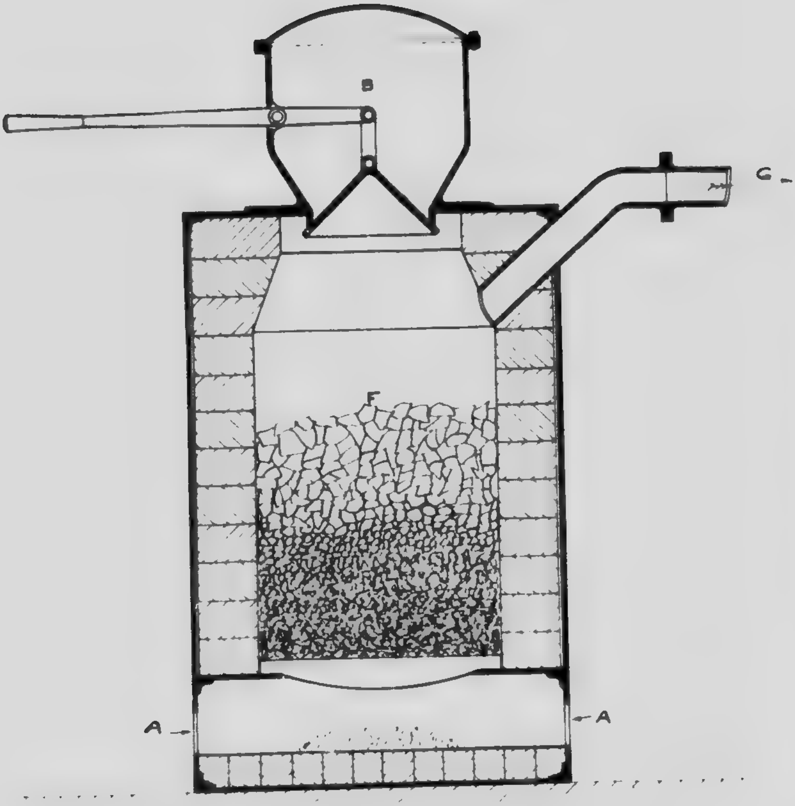

Fig. 38. Diagram of simple form of gas producer.

THE
COALS OF CANADA:
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VOL. II

PART VIII

GAS PRODUCER TESTS

BY

R. J. DURLEY

PART VIII

GAS PRODUCER TESTS

R. J. DURLEY

GAS PRODUCERS AND THEIR METHOD OF WORKING.

As an introduction to the discussion of the trials of Canadian coals made in the experimental producer plant at McGill University, an elementary account of the theory and action of the gas producer will be found useful. Gas producers differ in design according to the fuel with which they are to be operated and the purpose for which the gas is to be employed. Gas for power purposes, to be used successfully in an internal combustion engine, must be cleaner and more uniform in composition than is necessary in the case of gas to be used only for fuel or metallurgical work. The preparation of "coal gas" by distilling highly bituminous coal in air tight retorts is, of course, the usual process for making gas for city supply, and this gas, when properly cleaned, can be used for power purposes. Such gas must be clearly distinguished from that known as "producer gas," and is usually too expensive for use either in gas engines for power purposes or for metallurgical work. On the other hand, certain kinds of producer gas are largely used for city supply when specially treated to render them suitable for this purpose.

The term "producer gas" is used to denote the mixture of gases obtained by passing air, or a mixture of steam and air, through a body of incandescent solid carbonaceous fuel: coal, coke, peat, or wood are all successfully used. A blast furnace producing pig iron is, in fact, an example of such a producer on a large scale, and blast furnace gases can be used either for firing boilers or (after proper cleaning) for supplying gas engines for power purposes.[1] In a blast furnace air alone is passed through the heated coke which forms so large a part of the charge of the furnace.

The simplest kind of gas producer is one using a fuel (such as coke) containing little or no volatile combustible matter and supplied only with air. The arrangement of a simple updraft producer is shown in Fig. 38, and it will be seen to contain a somewhat deep bed of fuel, **F**, surrounded by a gas tight envelope of plate iron, with proper provision for the supply of air at **A**, the introduction of fuel at **B**, and the removal of the resulting gases at **G**.

The general nature of the actions occurring in such a producer can be readily followed by any one having a slight knowledge of chemistry. With a sufficiently deep bed of fuel and a properly adjusted air supply, it will be found that the carbon of the fuel unites with the oxygen of the air to form carbon monoxide (CO), a combustible but poisonous gas, which, if supplied with a further amount of air at a proper temperature, will unite with more oxygen and form carbon dioxide (CO_2), the product of complete combustion of carbon and oxygen. The formation of carbon monoxide in the gas producer thu involves partial combustion of the carbon, and is accompanied by the evolution of only about 30 per cent of the heat which could be produced b burning the same weight of carbon completely to carbon dioxide. This 3 per cent is lost, being dissipated by radiation and carried off as sensible hea in the hot producer gas; the balance (about 70 per cent) can be utilized b burning the producer gas with more air. The efficiency of a producer, suc as that just described, can, therefore, not exceed about 70 per cent, since a producer of 100 per cent efficiency is one giving gas which, if burnt, would develo 100 per cent of the calorific value of the fuel employed[1] The *efficiency* *a producer is*, in fact, the ratio $\frac{\text{Calorific value of gas produced}}{\text{Calorific value of fuel consumed}}$

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[1] See, for example, Trans. A.S.M.E., June, 1910, for an account of a very large blast furnace gas engine power plant.

It has been found experimentally that the heat produced by burning o pound of carbon to carbon monoxide (CO) amounts to about 4,200 B. T. U while if the resulting $2\frac{1}{3}$ pounds of carbon monoxide are permitted to uni with a further supply of oxygen so as to produce $3\frac{2}{3}$ pounds of carbon dioxide, an additional 10,450 B.T.U. is generated. The calorific value of one pound of carbon is, therefore, 14,650 B.T.U. when it is completely burnt to carb dioxide. Hence, as has just been explained, the heat efficiency of the proce of formation of carbon monoxide will be $\frac{10450}{14650}$ or 71·3 per cent under ideal or theoretically perfect conditions. In an actual producer of the kind described above even this figure cannot be reached, and it is necessary to adopt some means for utilizing a portion of the heat which would otherwise be wasted. This can be done most simply by mixing a proper amount of ste with the air supply.

If steam be passed over incandescent carbon, a chemical reaction occurs which splits up the steam into its constitutents, hydrogen and oxygen, an the oxygen, under suitable conditions of temperature, unites with the carbon usually forming both carbon monoxide and carbon dioxide. The gas resulti from this process will, therefore, under ideal conditions, be a mixture of hydrogen, carbon monoxide, and carbon dioxide (the latter in small amoun if conditions are favourable). The dissociation of the elements of the stea however, requires more heat than can be furnished by the combustio carbon with the resulting oxygen; hence, on the whole, the formatio "water gas," by passing steam over red hot carbon, is characterized by lowering of the producer temperature because of the heat absorbed. if heat is not supplied from an external source or from some other che reaction, the temperature will soon fall so low that the decomposition steam ceases. This necessary supply of heat could evidently be fur by carrying on the formation of "air gas" in proper quantity, as explai in the preceding paragraph, and in many actual gas producers the two processes are in fact carried on simultaneously, the supply of steam be proportioned to that of oxygen that the heat resulting from the formation of "air gas" by burning a portion of the carbon to carbon monoxide by means of the oxygen of the air, is used up in maintaining the "water gas" reaction by decomposing the steam. The resulting gas, is, therefore, composed of hydrogen, carbon monoxide, and a proportion of carbon dioxide, the whole diluted by nitrogen and other inert gases derived from the air supply.

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[1], [2], For notes as to the meaning of terms such as "Calorific Value," "British T Unit," etc., and as to methods and units of heat measurement, see Parts VII and IX this volume.

It should be stated that in the formation of "air gas" a proportion of carbon dioxide is always formed, in addition to the carbon monoxide, its amount depending upon various circumstances, one of which is the temperature of the producer. Further, should the fuel used be one which (like anthracite or coke) contains any compounds of hydrogen and carbon, the resulting gas will probably contain a proportion of volatile or gaseous hydrocarbon compounds. The following table gives analyses showing (a) the composition of a sample of gas furnished by a producer using anthracite coal and supplied with both air and steam, which may be taken as typical of ordinary "producer gas" as used for gas engine work; (b) the composition of typical "air gas" in which the supply was air containing only a very small proportion of water vapour and the fuel was coke; (c) the composition of "water gas" made by blowing steam over red hot coke.[1]

TABLE XXVI

Composition of Gases by Volume

	(a) Producer gas	(b) Air gas	(c) Water gas
Carbon monoxide	27·6	32·6	44·0
Carbon dioxide	3·0	1·4	3·3
Hydrogen	15·3	1·0	48·6
Methane	1·1	—	0·4
Nitrogen, etc.	51·8	65·0	3·7
Total combustible gases	44·3	33·6	93·0
Fuel	Anthracite	Coke	Coke

Anthracite and coke, the fuels used in generating the gases whose compositions are given above, contain a very large proportion of fixed carbon, typical analyses of these fuels being somewhat as follows.

TABLE XXVII

Composition of Anthracite and Coke

Fuel	Fixed carbon	Volatile matter	Ash
Pennsylvania anthracite	85·0	8·5	6·5
" coke	89·0	1·3	9·[illegible]

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[1] Taken from Dowson and Larter's "Producer Gas," p. 21, 1906 edition.

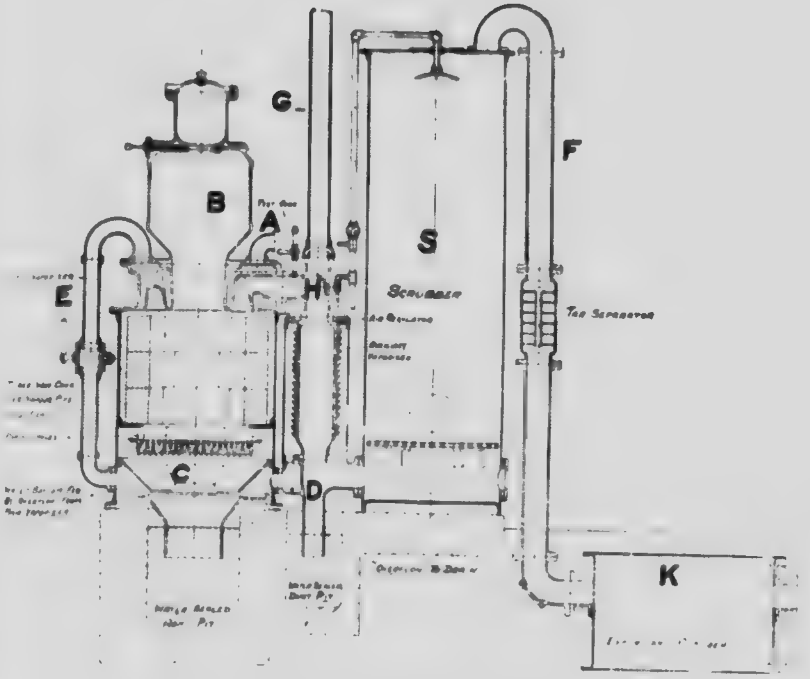
It is thus evident that if anthracite or coke of good quality is used in gas producer, the resulting gas should contain only a very small proportio of hydrocarbon compounds, and this is, in fact, found to be the case.

When gas is to be generated from fuels such as bituminous coal, wh contain a considerable amount of hydrocarbon compounds and give off large quantity of volatile matter on heating, the problem is a much mo difficult one especially if the gas is to be used for power purposes. This because the working of the producer itself is more complicated than wh bituminous fuels are used, and the tarry matters and products of distill arising when the coal is [illegible] must be dealt with in such a way to avoid stoppage in the producer itself, in the pipes, and in the passages and valves of the engines. This aspect of the question is considered later [illegible] and here [illegible] by adopting special designs of producer and [illegible] apparatus, coals containing as much as 40 per cent of volatile m have been [illegible] employed for power gas generation.

GAS PRODUCERS FOR NON-BITUMINOUS FUELS

A sectional view of a gas producer for use with fuel containing [illegible] no volatile matter is given in Fig. 39, from which it will be seen [illegible] arrangement of Fig. 38 is here modified so as to provide for the [illegible] supply of steam, and the apparatus is intended to be worked as a "suction" producer, in which the engine itself draws into the producer the quantity of air needed for its operation. Slight constructional changes would be ne if the producer were of the "pressure" type, in which the air is blown [illegible] fan, or if the draft were maintained by the action of an exhauster. [illegible] steam needed could, of course, be supplied by a separate boiler, but as [illegible] would involve additional expense, and would require more or less con attention, it is usually desirable, especially in small installations, to [illegible] the producer so as to generate its own steam. The particular [illegible] in Fig. 39 is that of Ruston, Proctor and Co., Ltd., Lincoln, [illegible] Producers of this type are built by many well known firms in [illegible] America.

In Fig. 39 the upper part of the producer [illegible] vaporizer or boiler, which is heated by the fuel [illegible] and [illegible] propor as to evaporate as nearly as possible the [illegible] water [illegible] steam [illegible] the air supply. [illegible] B air enters at **A**, passes over the heated water and carries the required [illegible] of steam along the pipe **E** [illegible] **C** below the grate. [illegible] leaving the upper part of the [illegible] passes through a water seal **D** enters the bottom of a wet scrubber **S** consisting of a cylindrical vessel containing a body of loosely packed coke through which water trickles cooling and washing the gas on its upward passage. From the wet scrubber the pipe **F** conducts the gas into an expansion box **K** then to the engine. For starting the producer, a small hand fan [illegible] shown and a [illegible] pipe **G** leading to the atmosphere is provided, so when starting [illegible] blown into the space **C**, [illegible] **H** is [illegible]

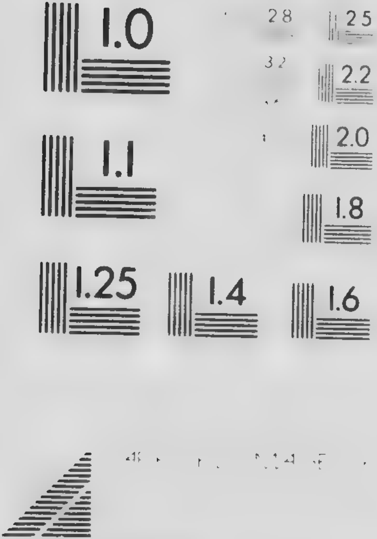

G
B
A
S
E
H
Scrubber
Tar Separator
Air Regulator
C
D
F
K
Overflow to Drain
Water Sealed Dust Pit
Water Sealed Ash Pit

[illegible]

[illegible]

MICROCOPY RESOLUTION TEST CHART

[illegible]



[illegible]

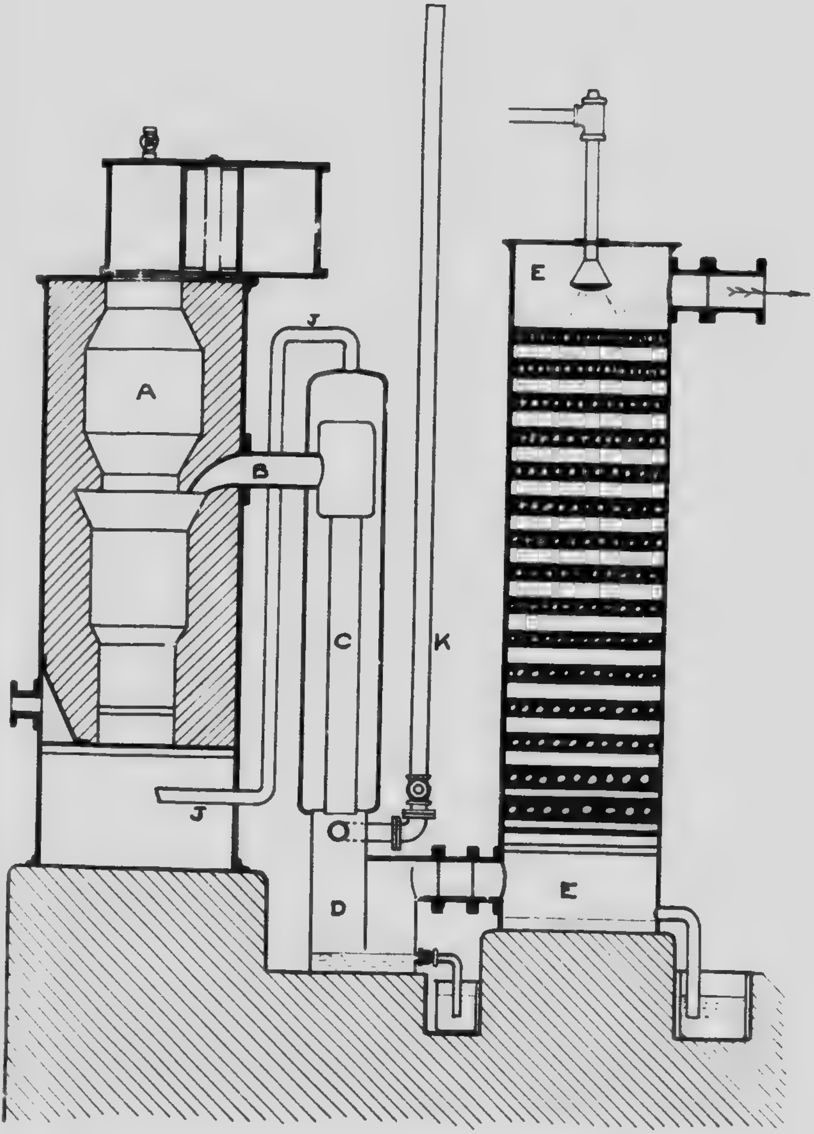


Fig. 40. Suction gas producer (Pintsch).

atmosphere, and the producer works under slight pressure, whereas in regular running the pressure in the whole system is slightly less than atmospheric. Suction producers of this type are in use up to about 500 H.P.; larger producers are usually of the pressure type, in which air is supplied by a blower or steam jet, and the whole apparatus is under a plenum.

It should be noted that in suction gas producers the vaporizer or boiler is frequently placed in the pipe leading to the scrubber, and not in the producer itself. An apparatus of this kind is shown in Fig. 40, which represents the Pintsch suction producer. Here the hot gas from the fuel bed leaving the producer by the pipe **B** passes through a vertical tube **C** in what is really a small boiler, fed by a gravity water supply, and discharging steam at atmospheric pressure by the pipe **J** into the space below the grate of the producer. Automatic adjustment of the steam supply is arranged, so as to suit the requirements of the fuel and load. The producer is provided with a dust trap **D** and the usual wet scrubber **E** and its accessories.

For the operation of an anthracite or coke producer, provision must, of course, be made for poking the fire, for the removal of ash and supply of fresh fuel, and for getting rid of any dust or refuse which may be deposited in the pipes or scrubbers. The chief troubles to be guarded against arise from the formation of clinker in the producer, or from gas explosions in the producer or pipes; also there is the possibility of gas poisoning if any leak or opening permits the escape of gas containing carbon monoxide into the producer room—or engine room. The latter is evidently less likely to occur in a suction plant than in one of the pressure type. A few words regarding these matters will not be out of place.

The term clinker in a gas producer is used to denote the fused ash of the fuel. If the temperature in the incandescent zone of the fuel bed is such that the ash melts as it is formed, there is a tendency for the melted ash or clinker to adhere to the walls of the producer, or to trickle down and cause trouble by solidifying in a cooler part of the fuel bed or in the bed of refuse lying above the grate. Sometimes a ring of clinker grows out from the wall of the producer and seriously interferes with the regular downward movement of the fresh fuel which ought to occur as that below is burnt away. In such a case it is necessary to remove the adherent mass by poking. The trouble may evidently be avoided either by using a fuel whose ash has a high melting point, or by working with a low temperature in the fuel bed. The latter result is easily obtained by increasing the proportion of steam in the air supply, but too low a temperature is undesirable, since it is found that with very low producer temperatures the resulting gas will be high in carbon dioxide and low in carbon monoxide; the calorific value of the gas generated will thus be lessened. The usual temperature in the heated zone of a gas producer is about 1,500° to 2,100° F.[1]

The risk of gas explosion in a properly operated gas producer plant is very slight. In order to produce an explosive mixture, the gas after leaving the fuel bed must be mixed with air, and this can only occur through leaky joints.

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[1] See Bulletin 393, U. S. Geol. Survey, pp. 15-27.

valves, or cocks in a suction plant, or by the improper use of openings, as ash pit, cleaning, or poke hole doors. The pipe system should alwa provided with a sufficient number of water seals, like that shown a bottom of the gas outlet pipe in Fig. 39, so that the effect of a gas explos the piping will simply be to blow out the water in one or more of the When cleaning out a scrubber or gas holder, no fire or light should be al in the producer house and all precautions should be taken to avoid poss of explosion.

Carbon monoxide is the only poisonous constituent of producer it is inodorous and occurs in sufficient amount to render the gas dang to human life if inhaled. Every care should, therefore, be taken to gainst leakage, and the producer house must be well ventilated. W cleaning is to be done it is very imprudent to enter a scrubber, gas hold any part of the installation until it is completely cleared of gas, an been blown out with fresh air. Again, in starting a suction plant must be taken that the engine is not in such a position that both ga air inlet valves are open, as in this case gas might possibly be d through the producer by the starting fan and thence into the engine roo Unburnt gas should not be allowed to escape from test cocks or orifices into the producer or engine room.

If a man is affected by carbon monoxide poisoning, he should be at removed into warm fresh air, and if insensible, the first-aid measures req are artificial respiration or the administration of oxygen. Exposure to is to be avoided. Although thousands of gas producer plants are in use cases of serious poisoning or asphyxiation occur.

On account of the fact that with a suction producer the pressure w the gas system is less than that of the atmosphere, any leakage occurring wh the engine is working will be from the air into the producer or piping. Wi a pressure plant, however, the leakage is outwards, and for this reason plants require more care to guard against possible leaks

The efficiency reached by the best gas producers in practice is hi Well designed installations working with suitable fuel have produced whose calorific value is as much as 85 per cent of that of the fuel burn even in small sizes. It is probable, however, that in every day work the efficiency of the ordinary suction producer does not exceed 75 to 80 cent and most installations working with bituminous coal show a conside lower efficiency than this.

It should be noted that when producer gas containing hydrog hydrocarbon compounds is burnt, the heat given up by the produc combustion is greater if the steam formed is condensed than if the ste not so condensed, because of the relatively large amount of heat given ou each pound of steam in being turned to water. When speaking o calorific value of such a gas, it is, therefore, necessary to know whethe higher value (allowing for the condensation of any steam formed) lower, or effective, value is meant. The two quantities often differ much as 10 per cent. It seems right to take the lower value in gas pr ed, since the products of combustion are always above 212 F. when they ve the engine, and the steam they contain, therefore, is not condensed.

GAS PRODUCERS FOR BITUMINOUS FUELS

Gas for use in gas engines must be clean, that is, practically free from st or tarry matter which will cause obstruction in the passages or undue wear of the working parts of the engine. Such gas should be delivered to the engine at as low a temperature and at as high a density as possible, so that the engine may take in a charge having the greatest possible heat value. The gas should be uniform in quality and uninterrupted in supply, whatever the rate at which the producer is worked, and the operation of the producer plant should involve but little supervision and manual labour on the part of the attendants.

Gas producers using bituminous coals have been successfully used for industrial purposes, such as cement burning, steel melting, and the like, since the introduction of the Siemens producer and furnace in 1861, but such producers are usually of considerable size, and furnish gas which is neither clean nor cool. Freedom from tar, and low temperature of gas, are qualities of little or no advantage for furnace work, and fuel gas producers are, therefore, simpler and less difficult in operation than is the case with producers supplying gas for power purposes. A coal may be capable of giving satisfactory results in a large fuel gas producer, and may nevertheless give trouble when burnt in a producer furnishing gas for power purposes, especially if the producer is a small one. Fuel gas producers[1] will not be discussed here, but the construction and operation of a few leading types of power gas producers will be described, in order to illustrate the special difficulties involved in the use of bituminous fuels. Such fuels form the major part of the world's fuel supply, and power gas plants must be capable of utilizing bituminous coals if they are to compete successfully with steam plants under any but exceptional circumstances. As will be seen from the following notes, however, the design of power gas producers for bituminous fuel is still undergoing development.

The composition of certain typical gases made from bituminous coal for power purposes is shown below:—

TABLE XXVIII

Composition of Typical Gases from Bituminous Coal.

Type of Producer............	R. D. Wood	Westinghouse	Mond
Moisture	4·21	1·39	2·0
Fixed carbon.....	53·16	74·28	65·0
Volatile matter ..	35·41	16·01	27·0
Ash	7·22	8·22	6·0

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[1] For a description of typical forms of fuel gas producers see Sexton, Fuel and Refractory Materials (Pub. Blackie and Son), Chap. VII

TABLE XXVIII [illegible]

Type of Producer	R. D. Wood	Westinghouse	Mond
Gas (per cent by volume			
Carbon monoxide	23·4	18·4	15·3
Carbon dioxide .	7·9	7·9	13·2
Hydrogen . . .	17·1	12·6	19·35
Methane.	2·1	2·6	3·85
Oxygen . .		0·5	
Nitrogen, etc .	49·5	58·3	48·3
Calorific value (lower B.T.U. per cub. ft.	150·0	117·8	141·7

These figures may be compared with those of Tables XXVI and XXV and with the analyses given later in Table XXXIII (Summary Record of G Producer Tests

If attempts are made to use bituminous coal in producers of such t as are shown in Figures 38, 39, and 40, the first effect of the introduct of a portion of fresh fuel is that a quantity of the volatile matter is driven by the heat of the already incandescent fuel bed. The resulting gas is the charged with hydrocarbons, the products of partial distillation of the fr fuel, as well as with dust arising from the ash of the fuel bed. The ta matter and dust are partly deposited in the pipe system, and partly remov in the scrubber, which rapidly becomes clogged, but a large amount of obje tionable material passes over to the engine, where it soon makes its prese manifest by obstructing the ports and passages, and especially the gas a air valves, so that in a short time the engine ceases to work.

But this is not all; if the bituminous coal employed is of a caking quali the fresh fuel will tend to form a more or less solid layer adhering to the wa of the producer, and permitting the formation of a hollow space as the re of the fuel burns away below. This layer has to be broken down by pokin a process which disturbs the regular operation of the producer, and is liable t cause rapid changes in the quality and composition of the gas generated, eve if it does not render the supply insufficient for the engine. The resistance the fuel bed to the passage of the gas will also change, and this change wi be shown by an increase or diminution of the pressure in the producer and pipe system. In fact, it will be found that an ordinary suction produc equipment which will work perfectly with coke or anthracite fails entire when tried with bituminous coal, even of non-caking quality. Difficult from the sticking or hanging of the fuel bed will, of course, be more serious a small producer than in a large one, for if the producer is of sufficient large diameter the fuel layers will tend to break down under their own weigh without the use of the poker.

Successful power gas producers for bituminous coal must, therefo provide means for:—

(1) Destroying or removing the tarry matter arising from the fresh fuel charged.

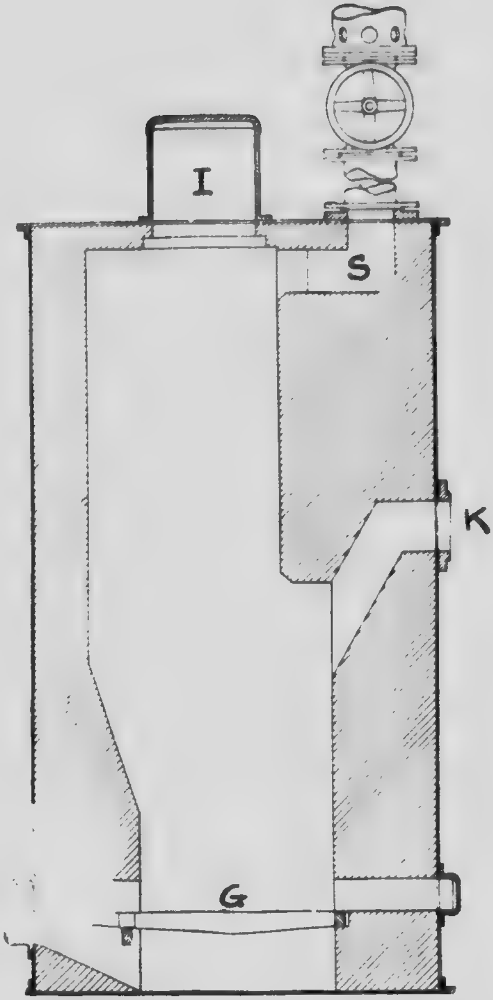

Fig. 11. Gas producer for lignite briquettes (Koerting).

2. [illegible] downward movement of the fuel as it is consumed, without excessive manual labour, thus obtaining a constant and uniform quality of gas.

3. Avoiding the loss arising from unburnt carbon in the refuse; and

4. Removing refuse without disturbing the operation of the producer.

The methods by which these ends have been more or less completely attained in actual producers will be seen from the descriptions which follow.

The products of distillation from bituminous coal, wood, peat, or other non-anthracitic fuel contain various hydrocarbon compounds which tend to break up into simpler forms, chiefly methane or marsh gas (CH_4), when exposed to a temperature corresponding to a bright red heat, this process being accompanied by the deposition of carbon in the form of lamp black or soot. Hence, if the vapours arising from the fresh fuel in a bituminous producer be drawn through the most highly heated zone of that or of a second producer, the whole or the greater part of the tar will be decomposed or burnt and further difficulty avoided[1] unless the lamp black gives trouble.

The only other alternative is to remove the tar by some kind of washing or cleaning process applied to the gas after it leaves the producer.

The Koerting producer (Fig. 11) is designed for use with briquettes made from lignite, and may be taken as an example of the type in which the tarry matter is destroyed by exposure to a high temperature within the producer. This apparatus is similar in general principle to a producer patented by Dowson in 1903, and consists of a vertical body some 8 or 10 feet in height, arranged as shown, with a grate **G** at the bottom, and a gas outlet **K** about half way up. Air is admitted both at the top and bottom of the producer and when running on lignite, which contains from 15 per cent to 30 per cent of moisture, good gas can be obtained with fair efficiency without the admission of additional steam. The gas outlet is so formed that as much as possible of the air entering at the fuel inlet **I** must pass through the heated zone of the fuel before reaching **K**. A passage **S** which leads from the top of the producer to the atmosphere is used for starting, and is closed by a valve during regular running. Provision is made for judging the condition of the fire and for poking, as required, by means of proper sight holes and poke holes. The position of the zone of highest temperature can be regulated by varying the relative amounts of air admitted at the top and bottom openings, in such a manner that the products of distillation from the freshly charged fuel are properly decomposed. The lower portion of the producer when working well contains only coked fuel resting on a bed of ash. The whole apparatus may be regarded as a combination of the so-called up-draft and down-draft systems, the passage of the gases being downwards in the upper and upwards in the lower portion. Such a producer would probably not work equally well with caking bituminous coal, as this fuel sticks or hangs in the producer much more than lignite, and poking in a deep producer of comparatively small diameter is not easy.

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[1] For a discussion of various methods of dealing with the tar difficulty in bituminous producers, see "Engineering," Jan. 31, and Feb. 7, 1908.

A producer plant in which the tar is decomposed in a second sep bed of hot fuel is shown in Fig. 42, which represents the Power and Min Machinery Co.'s arrangement of twin producers known as the "Loomis-Pet bone" system a scheme very similar to that originally proposed in Engl by Sutherland in 1882, and since tried by many other experimenters.

In this arrangement two producers or generators, connected at the to have valves **A** and **B** leading from the spaces beneath the grates to a boil or vaporizer. From the top of the vaporizer valves **C** and **D** conduct t cooled gas to either of two gas holders. Fuel is introduced through t hoppers **E** and **F**. The producers are worked in such a way that the p ducts of distillation from the generator that has last been coaled have to p through the hot coked fuel in the other generator. There are several way doing this. One method is to work the two generators in parallel, with dow draft, supplying air only, until the temperature rises sufficiently. During t period the tar from the top of each producer is decomposed in its own heate zone of coked fuel (anthracite or coke can be used for starting). The valve are then manipulated so that on supplying steam (without any air) to the b of (say) producer No. 1 and thus running it for water gas with up-draft, gases distilled pass downwards through producer No. 2 and are there fre from tar. During this "water-gas run" both producers will fall in temper ture, as the reactions occurring absorb heat instead of developing it, and the water gas produced, which is rich in hydrogen,[1] is usually led to a separ gas holder. When the action has proceeded sufficiently, steam is shut o and air admitted to both producers, which are worked down-draft as befor so that an "air-gas run" is made during which the producer temperatur rise, but will evidently be higher in No. 2 than in No. 1 where the water-g has been made. A second "water-gas run" is then made, but this time t steam is supplied to the base of No. 2, while the gases pass downwards throu No. 1 where the tar is dealt with. Another air blow follows, and the proc is repeated indefinitely. Fuel can be charged into either producer wh it is working with open top during the "air blow" period.[2] Installati of this type have given excellent results, but there is often some difficult in effecting the proper removal of ash and clinker without interference wit continuous operation, and close attention is required in order to mainta the uniform quality of gas and regular sequence of operations. The ga produced from bituminous coal is, however, of a good quality, and su plants are capable of economic working and good efficiency.

As an example of another arrangement for dealing with bitumino coal by destroying tar, the Westinghouse "double zone" producer, introduce in 1909, may be selected. This apparatus like the Koerting producer, is gene rally similar in principle to the Dowson producer of 1903, but contains mea for generating the steam it requires. It has no grate, the refuse being remove through a water seal at the base, and the plant includes many novel accesso

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[1] See p. 57.

[2] For an account of a test on a producer plant of this kind see Trans. A.S.M.E., V 29, p. 725.

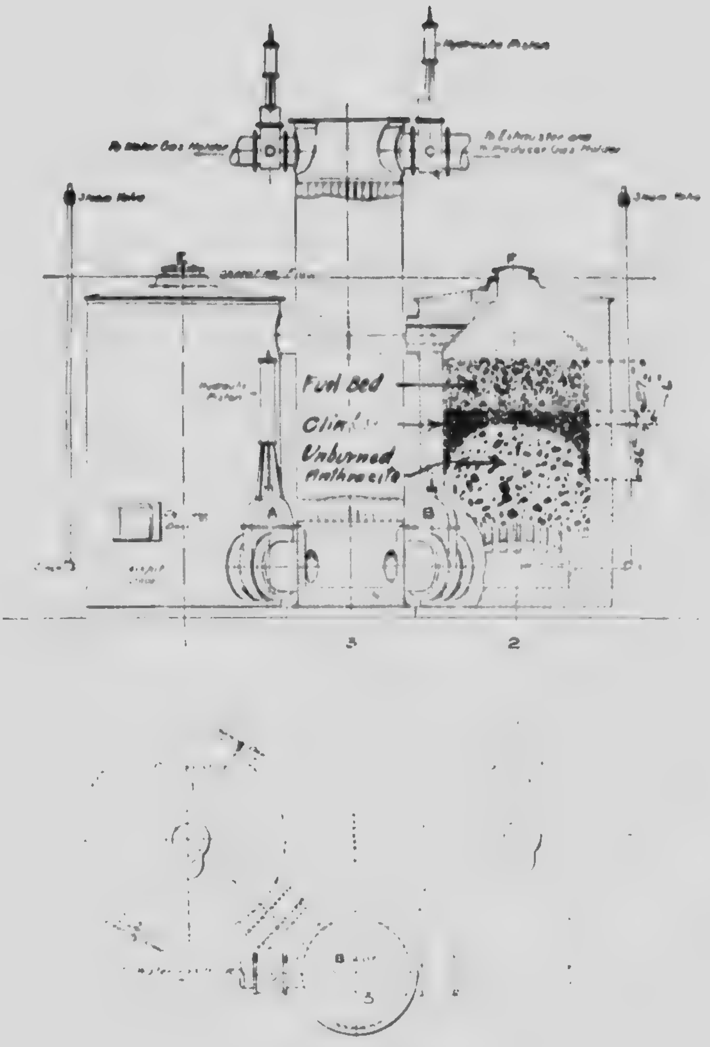

Fig. 42.—[illegible] downdraft gas producer [illegible] Power and Mining Machinery Co.

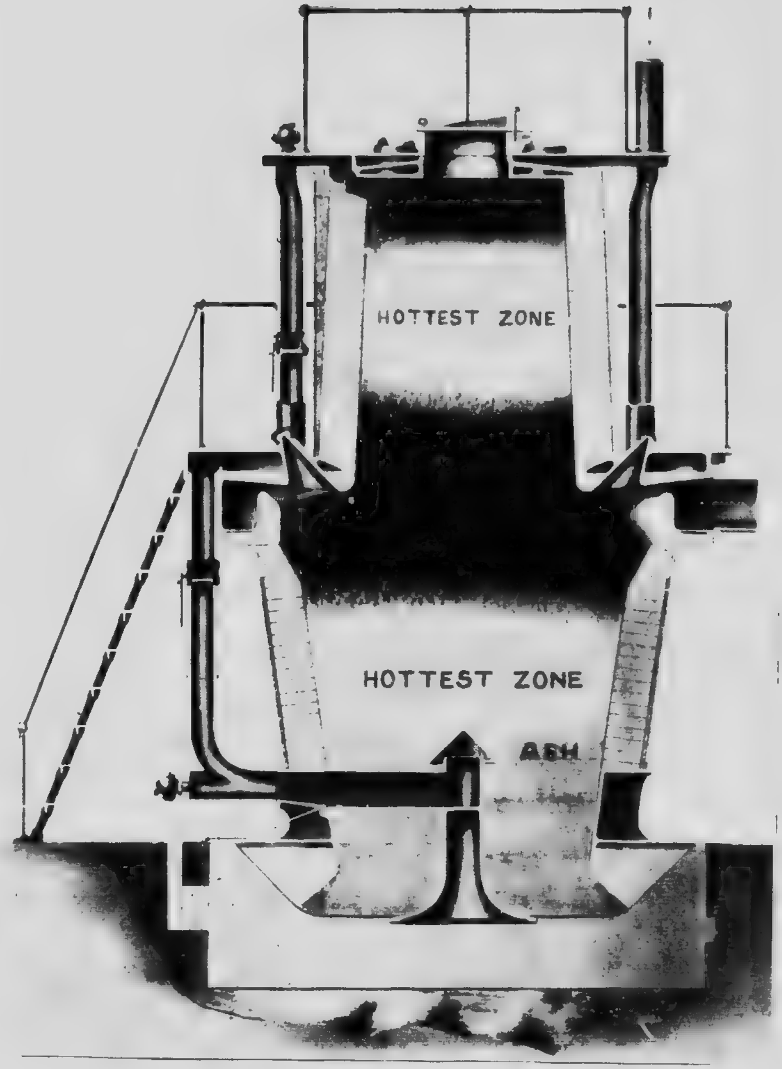

Diagram of Westinghouse double zone producer vertical section.

and features of construction. The producer is shown in Plate XLVII and in Fig. 43[1] from which it will be seen that the cast iron vaporizer, containing the gas outlet passage and a series of poke holes, divides the producer into an upper and a lower portion of different diameters. An air inlet pipe admits air to the steam space of the vaporizer, and vapour pipes, provided with supplementary air admission cocks, lead respectively to the spaces at the top of the upper portion of the producer and to the ash bed just above the water seal. Air and steam in any desired mixture can, therefore, be supplied to the fuel bed either at top or bottom, or at both, and the gas produced is drawn off by an exhauster from the central zone to the gasholder (if used) and engine. Sight holes enable the operator to judge of the condition and location of his fire. When in regular operation freshly charged fuel forms the top of the fuel bed, and rests on a layer of incandescent coked fuel through which the products of distillation pass. Towards the middle level of the producer the fuel is at a lower temperature, while the coke is completely burnt and another zone of combustion occurs near the bottom of the lower part of the producer. In connexion with this make of producer, a gas-washer of special type designed for the removal of dust, a mixing header, and a special pressure regulator are employed.

The producers so far described are of the type in which the tarry matter is destroyed by exposure to a high temperature or burnt by a special air supply. Many successful power gas plants, however, are in use in which the tar is removed from the gas, together with the dust, by power driven washing and cleaning apparatus. The producer plant successfully used by the U.S. Geological Survey in their St. Louis tests[2] was of this kind.

Probably the largest and most highly specialized power gas installations now at work are those using the Mond process,[3] in which the gas is mechanically cleaned, and this system is of considerable interest, especially as provision can be made for recovering certain of the by-products (such as ammonium sulphate) which are of commercial value. The Mond producer is of the up-draft type with a water sealed bottom. It is worked under slight pressure from a blower, and the entering air is mixed with a large amount of steam (about 2½ times the weight of coal burnt), with the object of keeping down the producer temperature, so that any ammonia formed may be recovered and there may be no trouble from clinker. The hot gas leaving the generator is, therefore, mixed with much undecomposed steam, and the mixture gives up its heat in a regenerator to the incoming blast. The gas is then passed through a mechanical washer, and enters special cooling towers where the ammonia is abstracted. Ammonia recovery is not usually practised in plants burning less than 30 tons per day, and the system as a whole is not easily applicable to small powers.

Taken from the Westinghouse Machine Co.'s circular W.M. 503.

See U. S. Geol. Survey, Professional paper No. 48, Report of Coal Testing Plant, Part III.

See Humphrey, Power Gas and Large Gas Engines for Central Stations: Proc. Inst. Mech. Eng., 1901, p. 41. Also Case, Jour. Soc. Chemical Industry, 1905, p. 596.

There are many designs of mechanical gas washers, most of which ap to be completely effective only within a somewhat narrow range of spee temperature. All involve the expenditure of a considerable amount of and power, and their use takes from the gas a portion of its combu matter. The gas is cleaned by means of a modified fan or correspo centrifugal apparatus in which finely divided spray catches the dust cles and carries them off, the spray and refuse being separated from th by centrifugal action. These machines are used on a large scale for cl blast furnace gas[1] for power purposes, as well as for producer gas.[2] satisfactory use in an engine, power gas should not contain more than 0.0 grain of solid matter per cubic foot, and the gas ought, at least, purified to this degree.

In large installations gas can be thus cleaned at an expenditure of ab 2 per cent of the power to be developed by the gas dealt with.

In several types of gas plant (as for example the Wilson producer pla a thorough cooling of the dry gas is carried out and is found to faci the removal of tar and dust by subsequent washing, because the parti to be dealt with are more readily wetted and entangled in the spray wh the gas is cool than when hot. The tar and dust are, of course, partia deposited in the cooling pipes, which are so designed as to permit of ea and frequent cleaning.

GAS PRODUCER TESTS AND METHODS OF TESTING

The selection of proper and reliable methods in gas producer tests one of the most difficult problems which confront the gas engineer, a when such tests are to be used, not to determine the efficiency of a given pr ducer, but to investigate the relative suitability of various coals for g producer use, as in the case covered by this report, the difficulty is not all diminished. As in the case of boiler trials, it seems at first sight a sim task to measure the fuel supplied to, and the heat value of the product livered from, the apparatus under test, in a given time, but when the w is attempted practical difficulties at once present themselves, and wi gas producer using bituminous coal troubles inherent in the nature of work to be done render the matter still more complex.

The main objects of a gas producer test, for whatever purpose it is must be to measure or determine:—

(1) The amount and calorific value of the fuel consumed by the p ducer in a given time;

(2) the amount of the heat value of this fuel actually utilized and av able in the gas supplied during the test interval to an engine or fur

(3) the amounts or items by which the loss or difference between and (2) can be accounted for;

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[1] For a description of a large installation of "Theisen" washers for a blast gas power plant, see Trans. A.S.M.E., June, 1910.

[2] For satisfactory use in an engine, power gas should not contain more than 0 grain of solid matter per cubic foot, and the gas ought, at least, to be purifie degree.

[3] The whole question of standardizing gas producer tests is now (1910) under consi eration by a Committee of the American Society of Mechanical Engineers.

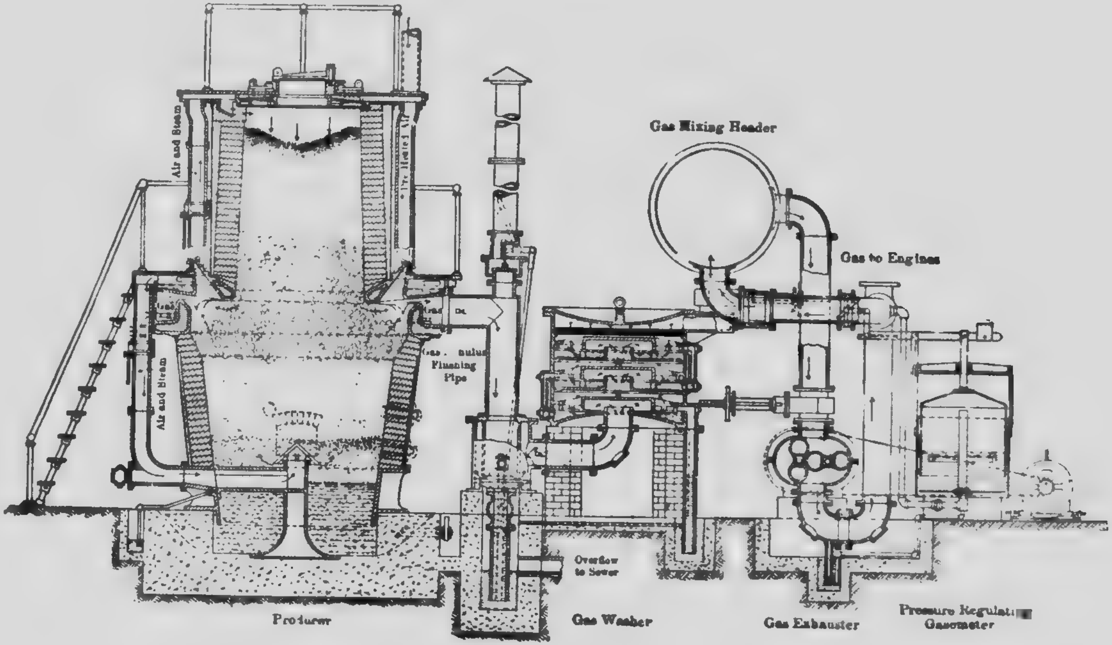

Fig. 13. Double zone gas producer (Westinghouse).

(4) the suitability of the gas for its intended use and the reliability and freedom from trouble of the producer when in service with the fuel to be employed.

The first difficulty occurring is that of determining the coal consumption, for a producer contains a deep bed of fuel, which as a rule can only be seen imperfectly at a few small sight-holes, and which may be composed to an unknown degree of red hot ash and refuse indistinguishable to the sight from good fuel. If at the end of a run one could judge the state of the fuel bed, and could be certain that its condition was exactly the same as at the commencement, this difficulty would disappear, and the coal fired or charged into the producer would be the same thing as the coal consumed. Actually there may be considerable discrepancy between these quantities, even in a comparatively long test, and the gas delivered by the producer may have been derived from a quantity of fuel greater or less than the amount actually charged into the producer.

The *rate of fuel consumption* may be computed in three ways:

(*a*). From the weight of coal fired, and an estimate of the difference between the fuel value of the contents of the producer at the beginning and at the end of the test period. In this estimate some assistance may be obtained from chemical analyses giving the composition of the ash and refuse drawn from the producer during the test and of the fuel bed (including its ash and refuse) at the end of the test.

(*b*). From a sufficiently complete analysis of the gases produced, a measurement of their amount, and a knowledge of the chemical composition of the fuel, a calculation can be made showing the amount of fuel required to produce the known quantity of gas, assuming that all of the carbon in the fuel consumed reappears in the gas generated.

(*c*). In a small producer, which can be mounted on a weighing machine and weighed continuously during the trial, the total weight lost between the times at which fuel is added indicates the amount of combustible consumed and moisture driven off; from this and other considerations the fuel consumed may be estimated.

Each of these methods has its drawbacks, but on the whole if a trial of sufficient length can be made it seems best to use (*a*), with proper precautions as to treatment of refuse, etc., although this method involves several serious sources of error, and correct judgment of the fuel bed conditions is almost impossible. The method (*b*) of working from gas and fuel analyses necessitates arduous and accurate chemical work, and even when correct and complete analyses are available, an unknown amount of volatile or gaseous constituents derived from the fuel may have been dissolved in and carried off by the scrubber or washer water, or may have been condensed or deposited in the pipe system. Tests of considerable length worked out in this way often yield results not in good agreement with the known rate of fuel weighing, and it is seldom possible in commercial tests to measure the amount of gas produced. The third method can obviously only be used with small producers; it is still necessary to allow for differences in the condition of the fuel bed, and a long run is needed in this case also, since the total weight of the ducer and charge is great as compared with the small losses or gains in w which have to be determined.

In order to carry out method (*a*) in a satisfactory manner, the followin points must receive careful attention.

(1) When the trial begins the producer must have been running intended rate of working, and with the fuel to be employed during the for a length of time sufficient to get the fuel bed into regular working cond This will usually need from three to ten hours, depending on the r working and amount of fuel in the producer

(2) Fuel must be added, and refuse removed, at stated intervals uniform quantities, so as to ensure as constant a condition of fuel b possible. The level of the fuel in the producer must be kept as unifor possible throughout the trial. It is not sufficient simply to have the lev the fuel the same at the end as at the beginning of the test; for exa if this result is obtained by filling in a lot of fresh coal just at the concl of the trial period, there will evidently be a great difference in the fu condition at the end as compared with that at the beginning.

Poking or disturbance of the fuel bed must be avoided as muc possible. This rule is often very difficult to carry out, especially with producers and those using bituminous coal, on account of irregularit in operation due to sticking of the fuel bed or formation of hollows wit it, in which case poking and irregular charging are unavoidable.

The length of test should be such that the possible error due to wro estimation of the fuel content of the producer is small, say 2½ per cen to 5 per cent. This can seldom be arranged for, and it is doubtful wheth many published tests of gas producers are accurate within these limits. I order to form an idea of the length of continuous run required, we may tak for example, a gas producer like that used in the U.S. Geological Survey te having a fuel bed 7 feet diameter and containing about 160 cubic fee 8,000 pounds) of coal, excluding the volume of the ash bed. It is evident tha in this case when working at a rate of about 15 pounds of coal per square foo of cross section of fuel bed per hour, or 570 pounds per hour, no less than hours run will be required to consume a weight of coal equal to the fu content of the bed. An error of 20 per cent, or 1,600 pounds, may easily be made in assuming the combustible content of the fuel bed to be th same at the beginning and at the end of the trial; hence, if the final c consumption is to be correct within ±5 per cent, at least 32,000 pound must be fired, or the test run must be continued for about 56 hours. On 24 hour run the possible error would then be nearly ±12 per cent, similar figures hold for producers of other sizes,[2] the possible error depending on the rate at which the producer is worked.

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[1] U. S. Geol. Survey, Professional Paper No. 48, Report of Coal Testing Plant, 190 part III, p. 984.

[2] See also U. S. Geol. Survey Bulletin 393, "Factors affecting proper length of tests

The input of the producer having been determined in the form of the number of pounds of fuel consumed, multiplied by its calorific value[1] per pound, the test must also include the measurement of the output, which is evidently the quantity of gas produced (usually in cubic feet) multiplied by its calorific value per cubic foot

The *quantity of gas* may be found either (*a*) by passing it through a meter which should be calibrated before and after the trial, at the proper rate or under the proper conditions of working; or (*b*) by a Venturi meter or by a Pitot tube: both these methods involve very careful and troublesome work if reliable results are to be obtained. A third method (*c*) requires the use of a gas holder of known capacity, the rise of which is noted over a period during which the whole of the gas from the producer is being discharged into it. The gas holder method is apparently simple, but very few gas plants are equipped with holders containing more than a few minutes supply, and difficulties are liable to arise from the bulging of the gas holder drum, rapid and uneven changes of temperature and pressure of the gas while the measurements are made, time lost in working valves, and from other causes, all of which may militate against the accuracy of the results. The meter method is usually the most satisfactory, although the cost of an efficient and accurate meter is large and the difficulty of calibrating it is considerable.

The *quality of gas* as indicated by its calorific value is best determined for practical purposes by burning the gas in an apparatus, such as the Junker or Boys' calorimeter, in which a metered volume of gas gives up practically all the heat generated to a continuous stream of cooling water, and this heat is measured by the rise in temperature of the cooling water as it passes through the calorimeter. Special difficulties arise when dealing with weak gas of low calorific value, in which case it is not easy to ensure complete combustion.[2] A description of such a calorimeter is given later. The calculation of the calorific value from the chemical composition of the gases is useful as a check, although difficulties in obtaining frequent and representative samples and the laborious nature of a complete analysis, render this method of comparatively little use in commercial work.

In connexion with the quality of the gas furnished by a producer, a satisfactory test should give complete information as to the suitability of the gas for its intended purpose, and this is not necessarily obtainable merely from the calorific value or chemical analysis. Among the points on which observations may be made are:—

(1) Amount of tar carried by gas and deposited in pipe system or entering engine.

(2) Kind and quantity of dust, collected in pipe system, removed by scrubber, and carried over to engine.

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[1] Methods of determining the calorific value of fuels are discussed in Part IX of this Volume. See also Part VII.

[2] For example of calculations with, and operation of, the Junker calorimeter, see Proceedings Inst. Mech. Engineers for 1908, Third Report to Gas Engine Research Committee, Appendix II. This also gives valuable information as to gas analysis methods for gas engine work.

(3) Amount of soot or lampblack formed or carried by gas

(4) Temperature of gas supplied to engine, and leaving producer

(5) Pressure or vacuum in producer and in various parts of pipe sy fluctuations in pressure during operation

(6) Uniformity in amount and quality of the gas

Tar and dust are most readily measured by filtering a measured quan of gas through special filter shells or papers. The amounts deposite the pipe system can only be determined by periodical cleaning

Observations of *temperature of gas leaving the producer* are extre valuable as an aid to effective control of the producer's working. S or gradual changes in this temperature indicate alterations in the wo condition of the fuel bed, which can then usually be dealt with in to avoid trouble from considerable variation in calorific value or pr of gas. Fluctuations in calorific value or gas pressure are especially tro some when they necessitate continual alterations in the adjustment o engine valves.

When testing various coals in a gas producer, it is necessary not to make such observations as are possible on the efficiency and eco of the producer with the various coals tested, but also to record any info tion obtainable as to the relative adaptability of the various sample operation in the producer. Experience gained in regard to the follo points is valuable:

(1) Labour required to handle the coal and work the fire in the p ducer. This is affected by the caking and clinkering qualities of the itself, and by the fact that the producer may be operated with fuel bed ditions unsuited to the particular fuel under test. For instance, an insuffi supply of steam may lead to trouble from clinkering with a coal which w work well with a lower producer temperature. Or, the producer used be of a design unsuited to the particular fuel.

(2) Labour required to handle ashes and refuse.

(3) Trouble arising from tar and volatile matter in coal.

(4) Trouble arising from packing of the fuel bed, due to nece for excessive local poking, or due to the particular size and nature o pieces of fuel. For example, with certain lignites, which break up into s pieces on heating, or with certain sizes and kinds of anthracite, trouble packing may easily occur.

(5) Effect of depth of fuel bed on the working of the producer each coal. Fuels such as peat will require for efficient working a dep fuel bed very different from that which will give good results with a such as hard coal.

(6) Trouble arising from deposition of soot or lampblack. This mat if deposited in the producer, often seems practically incombustible, a very difficult to deal with.

(7) Difficulties due to nature and amount of sulphur in coal. T have been occasionally manifested in prolonged runs with certain c and have caused corrosion of iron work expo[illegible] the moist gas.

8) Effect of inherent moisture of coal on the amount of steam required is very marked in lignites, many of which work well in a producer hout any steam supply at all.

The accurate estimation of the various individual *heat losses* in a gas ducer test is almost impossible, as will be seen when we consider the ficulties surrounding the measurement of the various quantities on which h estimation depends. For the ordinary commercial testing of producers, a series of tests like that now reported, intended as a basis of com son of various coals, such detailed results are fortunately not necessary. e losses in question may, however, be indicated below. The chief items

Losses in producer itself
Radiation
Heat lost in ash and refuse withdrawn
Heat lost in evaporating moisture in coal
Heat value of combustible in ash and refuse withdrawn
Heat value of carbon or soot deposited in producer

Losses in piping, vaporizer, scrubbers, and gas cleaning apparatus
Radiation.
Heat used in warming water in scrubber and washer and in saturating gas with water vapour.
Heat value of combustible deposited in vaporizer and piping.
Heat value of combustible dissolved and carried off by scrubber and washer water

And finally:—

Heat carried away to gas holder or engine due to high temperature of gas.

The heat expended in the formation of the necessary steam supply would be a loss if the producer did not generate its own steam. The heat value of gas or coal corresponding to the power used in driving, washing, blowing, hausting machinery should, of course, also be taken into account

The practical results obtained with actual producers show that having regard to all these losses, their total amounts appear to be about as follows:—

Kind of Producer.	Total losses in producer plant per cent of calorific value of coal fired, full load
Suction producer, small size, using anthracite	15% to 25%
Suction producer, large size	10% to 20%
Small producer using bituminous coal.	25% to 45%
Large producer using bituminous coal with regenerative plant, etc.	20% to 30%

When the producer is worked below its proper capacity, the efficiency s, of course, appreciably diminished.[1]

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[1] Very complete tests (under varying conditions of output) on a Mond bituminous oal producer are given by Professor Bone in the Journal of the Iron and Steel Institute, 1907, p. 126, 1908, p. 206.

In practice the quantity which is of paramount interest to the p ser is not the efficiency of his producer or engine, but the overall efficien power production from coal pile to engine shaft, and this is [illegible] [illegible] than the separate efficiencies on which it depend

EQUIPMENT OF EXPERIMENTAL PLANT FOR GAS PRODUCER TESTS—CANADIAN COALS

From the preceding paragraphs it is possible to obtain some idea of difficulties which have been encountered in successfully operating a perfected [illegible] producer plant suitable for the [illegible] of all types of coal lignite now worked commercially in the Dominion of Canada. These differ widely in composition and vary in character from a true lignite taining 10 per cent of ash, 30 per cent of volatile combustible, and 25 cent of moisture, to an anthracite with 78 per cent of fixed carbon 12 per cent of volatile matter and hardly any moisture. Samples the extreme west of the Dominion and from the Maritime Province [illegible] from intermediate regions had to be treated, and questions of t [illegible] storage, and handling had to be considered.

The conditions of the case were, therefore, such that it was nec to use quantities only just large enough to be capable of giving the req results, and in settling the capacity of the experimental producer plant was decided to work on a comparatively small scale. Each lot of coal to furnish sufficient material for chemical work, boiler tests, and, in m cases, coal washing and coking tests, as well as for the producer work. I well known that operating difficulties are less noticeable in a large than a small producer plant, and it was desired, if possible, to test the suitabi of the various Canadian coals for use in a producer plant of a size not bey the needs of the small power consumer. The installation of an engine producer plant capable of giving 30 to 40 B.H.P. was, therefore, resolved up and at the end of 1906, a 40 B.H.P. four cycle horizontal engine was orde from the National Gas Engine Co., Manchester, England, together wit suction producer, known as No. 1, and the necessary scrubbers and acces ies. All were of standard commercial type, and designed for use with anth cite coal. On delivery, the machinery was installed in a building erec for the purposes of the tests, and orders were placed for the gas was gas holder, exhauster, gas meter, and other apparatus required for test p poses. In the meantime the question of a producer of a type capabl dealing with the various bituminous coals was carefully considered, after communicating with leading builders on both sides of the Atla proposals were submitted (among many others) from such makers as Cro Brothers Ltd., Manchester, Koerting Bros., Hanover, the Gas Motoren Fab Deutz, the De La Vergne Machine Co., New York, and the R. D. Wood Philadelphia. None of these firms were prepared to give a definite un taking that their producers would handle all the coals to be dealt with du the tests, although several were ready to guarantee success with lignite o

One company, not named above, finally offered to build an experimental producer (No. 2), which was to be accepted if it met the test requirements. This producer was therefore built and tried in May, 1907, [illegible] encouraging but not completely satisfactory results, further being expected from it. The builders then announced that they were unwilling to spend more money on experimental work, and it was necessary to [illegible] the producer. Later, a communication was received from a German firm stating that they were prepared to furnish a 100 H.P. suction plant for any grade of coal, the producer to be built by Julius Pintsch, of Berlin, Germany. Although this would have involved work on a larger scale than was intended, the proposition was considered, but in February, 1908, after much correspondence and inquiry, the Pintsch Company refused to guarantee results unless they had a large sample of each kind of coal forwarded to them in Berlin, so that the producer might be specially designed. It was obviously impossible to comply with this requirement.

In the meantime, further correspondence was carried on with certain American companies, who claimed to have been making and working with success small bituminous producers, but investigation was followed by no useful result, as the claims made were in no case substantiated.

At the beginning of 1908, it seemed impossible to obtain from any responsible builder a small producer which would be capable of dealing with all the bituminous coals likely to be submitted for test, but it was known that a number of experimenters were at work on the problem and that successful developments were likely soon to take place. In these circumstances a new specification for a small bituminous producer was drawn up and sent out to a number of leading manufacturers. As a result, in February, 1908, a Canadian firm undertook the construction of a 40 H.P. producer which would successfully handle bituminous coals of certain specified grades, they agreeing to supply and erect the producer in Montreal and to remove the plant at their own expense if the results were not in accordance with their guarantee.

This producer (No. 3) was submitted to a series of tests extending over the period from June to September 1908. Alterations were made from time to time with a view to obviating the various troubles experienced with poor gas, tar, dust, and soot; but although dealing with a non-caking coal containing only a moderate amount of volatile matter and low in ash, it was found impossible to undertake continuous running with this producer, and the apparatus was finally removed from the laboratory.

The time spent in experimenting with and trying producer No. 3 was thus wasted, as far as the prosecution of the series of tests on Canadian coals was concerned; the period was, however, utilized as far as possible in getting the remainder of the plant into thorough running order. Changes were made in the gas washer, improving its performance and reliability, the pipe arrangement was modified, the meter system calibrated, and a series of tests run with the suction producer on anthracite and coke to accustom the staff to test conditions, and to make sure that a good working arrangement had been installed. The apparatus for gas analysis and calorimet was also fitted up and adjusted.

During the long period of correspondence and inquiry, it had becor evident that no builder could be found who was able to guarantee the sat factory operation of so small a producer with bituminous coal, althou several would have undertaken the task if a plant of larger capacity cou have been installed. Careful study of the various designs submitted, ho ever, seemed to indicate that it would be possible to design a simple produ more suited for the special conditions of this case than any of those offer In January, 1908, it was felt that a producer of the down-draft water-se type should be tried (in spite of the low efficiency to be expected with so coals with a producer of this kind), inasmuch as this type of producer is t only one which can be worked with an open top and which affords comple facility for poking and thus dealing satisfactorily with caking coals. Such producer (No. 4) was accordingly designed by Professor Durley.[1] It w ordered on March 26, 1908, was built in Montreal, and delivered and erect within five weeks. Satisfactory preliminary trials were made in May, 1908 and after some delay caused by the unsuccessful experimental work on pr ducer No. 3, four satisfactory runs, each of twenty-four hours duratio were made with producer No. 4 on two purchased samples of bitumino coal, of which one contained 36 per cent of volatile matter and 11 per cent ash.

During these trials good gas was made, the engine carried its load we and continuously, and the scrubbing and washing apparatus dealt satisfacto ly with the comparatively small amounts of tar and dust which left th producer. In order to avoid further delay, it was, therefore, decided to r the official coal tests on producers Nos. 1 and 4, the former being used o for anthracite and the latter for all other fuels. It may here be said th No. 4 producer was found to work satisfactorily with all of the coals teste although its efficiency was lower with caking coals than with non-caking coals on account of the considerable proportion of unburnt fuel which pass through the water-seal when continual poking had to be resorted to.

In the case of the anthracite samples, it was, of course, advantageous t be able to run tests on a suction producer of standard design in order to te the suitability of these coals for use with an apparatus of this type.

Building.—In order to accommodate the gas producer and engine equi ment, a light and well ventilated building 75 feet × 18 feet was erecte having 16 feet clear head room and provided with a hand crane of 2,000 pounds capacity. The producers were installed at the west end, and engine, gas holder, and auxiliaries were arranged so as to leave the necessa room for access and attendance. The building had a steel frame, w walls of two thicknesses of wire lath coated with cement plaster. The r was of the usual wood, tar, and gravel construction, and the floor of cemen

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[1] Drawings and a description of this producer are given later, see p. 75, Plate XLV I and Fig. 45.

Producers.—The final equipment of the plant thus included two producers: (*a*) a suction producer of the Dowson type, built by the National Gas Engine Co., Manchester, England, here referred to as No. 1, and suitable for burning anthracite or coke; and (*b*) a down-draft water-sealed producer designed by Professor Durley, built to his drawings by Alexander McKay of Montreal, and known as No. 4. These producers are shown in Figs. 44 and 45, and their leading dimensions are as follows:

	No. 1.	No. 4
Diameter of producer shell	2′ 7″	3′ 7″
Inside diameter of brick lining	2′ 0½″	2′-6″
Area of fuel bed.	2·3 sq. ft.	4·[illegible] sq. ft.
Effective maximum possible depth of fuel bed.	2′-3″	3′-6″ with extension 1′-0″ without "
Thickness of fire brick lining.	4″	6″
Overall height of producer from floor to highest point .	8′-0″	8′-8″ with extension 7′-2″ without "
Diameter of gas outlet pipe	3″	4″
Height and diameter of wet scrubber .	8′-0″ × 2′-10″	8′-0″ × 2′-6½″
Area of cross section of wet scrubber.	5·9 sq. ft.	4·92 sq. ft.
Height and diameter of dry scrubber		8′ 0″ × 2′-9½″

The suction producer (No. 1), and its vaporizing apparatus as shown in detail in Fig. 44, is rather different in design from the types shown in Figs. 39 and 40. Referring to Fig. 44, the fuel hopper **H**, grate, and producer lining are somewhat similar to those already illustrated, while the wet scrubber **S** presents no special features. The necessary amount of water for the steam supply is dropped into a tube leading to the bottom of a heating pipe **P** having ribs on its outer surface, which is exposed to a current of warm gas leading to the scrubber. The upper part of the producer forms the vaporizer hopper **V**, and the hot water from **P** trickles down from a circular trough over ribs past which the air from the inlet is also led. The air entering the producer is thus heated, and the water evaporated by the heat from the gases passing from the fuel bed. These are made to pass round the fuel hopper and inside the vaporizer casting on their way to the gas outlet. Air for starting is supplied by a hand fan; when running, the fan suction is closed and the air regulated by an adjustable inlet opening **A**. Cleaning doors **CC** are provided for the spaces above and below the grate, and at necessary points in the pipe system. The waste pipe **W** is opened to the atmosphere while starting up, and the combustible quality of the gas tried at the test pipe **T**. The coke in the scrubber is supported by the grating **G** and the scrubber water runs off through a water sealed pipe **Q**.

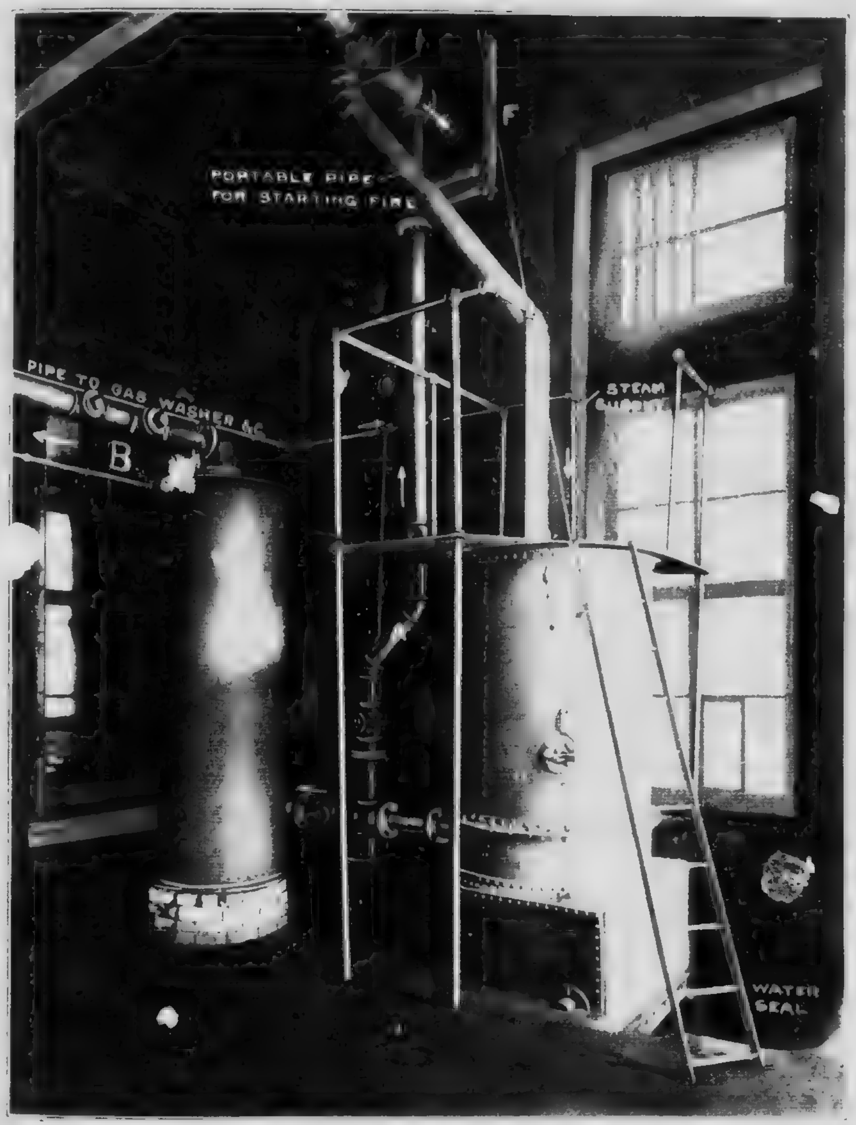
The down-draft producer (No. 4) is illustrated in Fig. 45, in which the wet or coke scrubber and connexions are not shown, as they were of the same construction as for producer No. 1. No vaporizer was used with No. 4 producer, nor was any provision made for preheating the air supply. It was felt that with some of the coals tested trouble from tar was almost certain to arise in a vaporizer of the kinds shown in Figs. 39 or 44, and owing to the late date at which producer No. 4 was available, it was impossible to fit [illegible] a vaporizer, either of coiled pipe embedded in the brickwork, or of the water jacket type, such as has been found successful in bituminous producers of well known makes. It was also desired to obtain a measurement of the steam used in each test; for these and other reasons the steam supply was taken from a separate boiler and led into the top of the producer by a ring pipe just below the top plate, the amount supplied being estimated from pressure readings on the two sides of a calibrated orifice placed in the steam main. A separate additional ring of plate, together with the necessary firebricks for lining, was provided and could be placed on top of the producer, so that the depth of the fuel bed could be increased if found necessary. All the coals tested were, however, used successfully without having recourse to this additional section. The firebrick lining of the producer was carried on a cast iron bottom plate and was separated from the shell by about 1" of asbestos packing, and the shell and lining could be removed by the crane without disturbing any pipe joints. The fuel in the producer rested on a heap of ash around which sufficient space was left to permit the exit of the gases; the direct draft to the outlet pipe was screened by a firebrick baffle **B**, supported by brick and iron and protected by its position from damage by poking. The burnt fuel was held up by a rocking grate **G** at the bottom of a firebrick slope, the grate having cooling prongs dipping down into the water-seal **W**. The open top of the producer could be wholly or partly covered by a sliding plate, and three sight holes (available also for poking if necessary) were placed in the shell of the producer.

Plate XLVIII is a photograph of the down-draft producer No. 4 with its charging platform, the hood and piping for starting on up-draft, the atmospheric waste pipe **A**, the starting fan **F**, the wet scrubber **W**, and the 4" pipe **B** leading to the gas washer and exhauster.

For starting this producer the water in the seal at the bottom was lowered, and the open top connected by a portable pipe and hood with a small exhaust fan; the producer was then worked with up-draft until a satisfactory fuel bed was obtained, after which a short run on down-draft was usually necessary before starting the engine, the small fan or the exhauster being used for this purpose, and the gas discharged to the atmosphere. With some coals it was found that this procedure could be somewhat shortened by starting with coke, but when this was done it was necessary to run on down-draft for a longer time before steady test conditions were established.

Engine.—The engine installed was of the regular horizontal four cycle type, built by the National Gas Engine Co., Manchester, England, having a single cylinder 12" diameter × 20" stroke, designed to run at 220 R.P.M. and capable at that speed of developing 40 B.H.P. with gas of 120 to 140 B.T.U. per cubic foot. Its construction and arrrangement are shown in Fig. 46, and it was provided with a water cooled flywheel and rope brake, and with magneto ignition. It was fitted with indicator gear, including a special w[illegible]er

Plate XLVIII.



Down-draft producer (No. 4). Department of Mechanical Engineering, McGill University.

cooled indicator connexion, and with means for weighing the jacket cooling water when required. Starting was effected by pumping up the compression space with explosive mixture and igniting this charge when the crank was turned a little past the dead centre and the piston was on the explosion stroke. The governor was of the hit and miss type, regulating speed by cutting out the gas charge entirely when in action

Gas Holder.—A gas holder of 100 cubic feet capacity was provided. It was loaded so as to give a pressure of about 3½" of water, and was constructed of No. 17 sheet steel, stiffened with angles as required. An escape pipe to the atmosphere was arranged so that the rising of the gas holder bell above a certain point automatically opened a relief valve. In this way sudden stoppage of the engine, or unexpected diminution in its rate of gas consumption, need not cause any interruption of the working of the producer. On leaving the gas holder the gas passed direct to the suction of the engine. It will be readily understood that the use of the gas holder was necessary in all cases where the gas had to be metered, and it was, indeed, used in all the official trials, although in several cases it would have been quite feasible to work with the suction of the engine only without the exhauster, had it not been for the necessity of measuring the gas

Exhauster.—Gas was withdrawn from the producer through the scrubbers and gas washer by means of a Sturtevant gas exhauster (a machine of the Root blower type), and was delivered through the meter to the holder. The exhauster required little attention beyond occasional lubrication with coal oil. It was provided with a by-pass and relief valve connecting its discharge and suction, so that the amount of gas actually delivered to the gas holder could be easily adjusted.

Gas Meter.—The meter used was a No. 50 Westinghouse of the standard oil sealed type. It was calibrated periodically by the aid of the gas holder, and gave satisfactory service; its rated capacity was 8,500 cubic feet per hour.

Gas Washer.—A gas washer furnished by the National Gas Engine Co. was placed between the coke scrubber and the exhauster. Considerable trouble was experienced at first with this machine, the shaft and bearings being too light for hard service and the balance defective. Its construction is shown in Fig. 47. The gas was passed from end to end of a cylindrical casing in which rotated a horizontal shaft fitted with ten revolving plates of which five were perforated. Stationary plates (A) secured to the casing separated the successive pairs of rotating plates (B and C), and water was admitted at the inlet end of the casing. The tarry overflow water escaped through five outlet pipes at the bottom of the casing and passed into a wooden trough fitted with baffles, in which practically all of the tar washed out by the apparatus was collected. A similar tar box dealt with the tarry water from the coke scrubber.

GENERAL ARRANGEMENT OF PLANT AND ACCESSORIES

As will be seen from the general arrangement of the installation, as shown in Fig. 48, the piping system was so laid out that the gas could be taken either:

a) from the suction producer (No. 1) through its coke scrubber direct engine; (b) from No. 1 producer through the scrubbers, gas washe hauster, meter, and gas holder to the engine or atmosphere; (c) from the draft producer (No. 1) through its coke scrubber direct to the engin from No. 1 producer through the scrubbers, gas washer, exhauster and gas holder to the engine or atmosphere. Provision was also m the pipe lines for by-passing any of the scrubbers, the gas washer, the the gas holder or the exhauster. Separate electric motors were prov the gas washer and for the exhauster, so that [illegible] fan was used for starting up No. 1 producer in the [illegible]

On leaving either producer the gas was first passed through scrubber through which a stream of water was dripping; this was then [illegible] box in which as much as possible of the t dirt was collected. The gas then passed through the washer. After the washer the gas could be passed if necessary through a sawdust a rectangular wood box provided with trays and packed with sa On leaving this the gas entered the exhauster and went through a box filled with excelsior; it was then delivered to the meter and thence the gas holder. The gas main was 1" diameter throughout.

It will be noted that when working with the exhauster, the pr wet scrubber, gas washer, and sawdust scrubber were under a pressure less than atmospheric, the remainder of the apparatus being under plenum.

The whole system was provided with water-seal boxes at interv arranged as to act as tar drips and also as safety valves in the case of an of pressure in any portion of the gas piping. Cleaning doors and co for pressure gauges, gas sampling pipes, and thermometers were fitted w necessary.

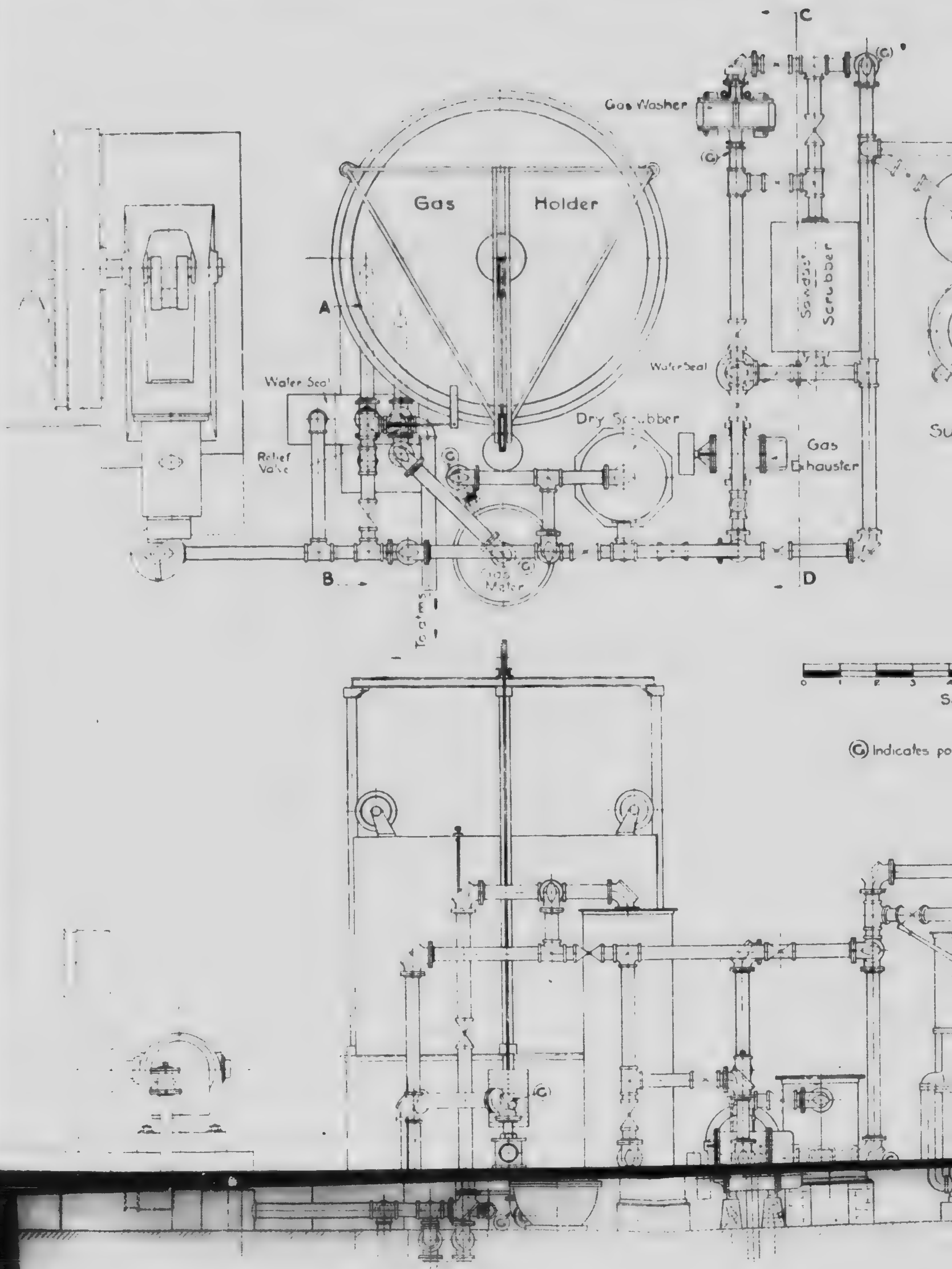
Pressure gauges on the gas piping were of the ordinary **U** tube reading in inches of water, and were arranged so that the losses of p could be traced along the whole system, and any obstruction could located.

The gas samples for analysis and calorimeter determinations wer from a sampling pipe connected to the 1" gas main just after le dry scrubber, and a test flame pipe was also provided. The gas was analysed after passing through the wet scrubber, gas washer, sawdus (when this was used), and dry scrubber.

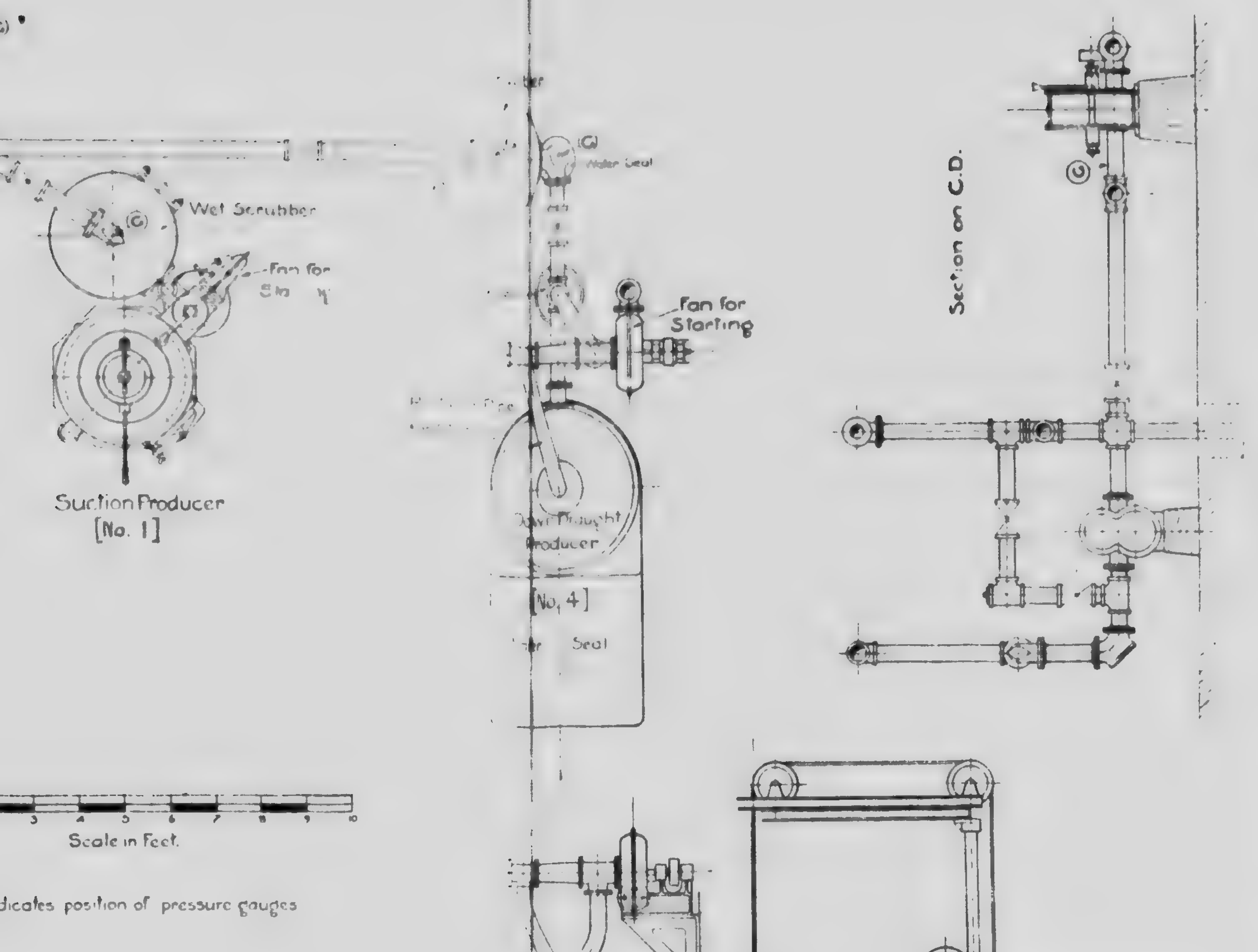
The gas calorimeter was of the Boys' pattern, as described in P of this volume.

The calorimeter as set up for use in the laboratory is seen in XLIX. The calorimeter **C**, with its two thermometers, and water me vessels stands next to its gas meter **M**. On the left is the gas gove which maintains a steady and uniform flow of gas to the meter.

The gas analysis apparatus and methods are described in Part IX volume.

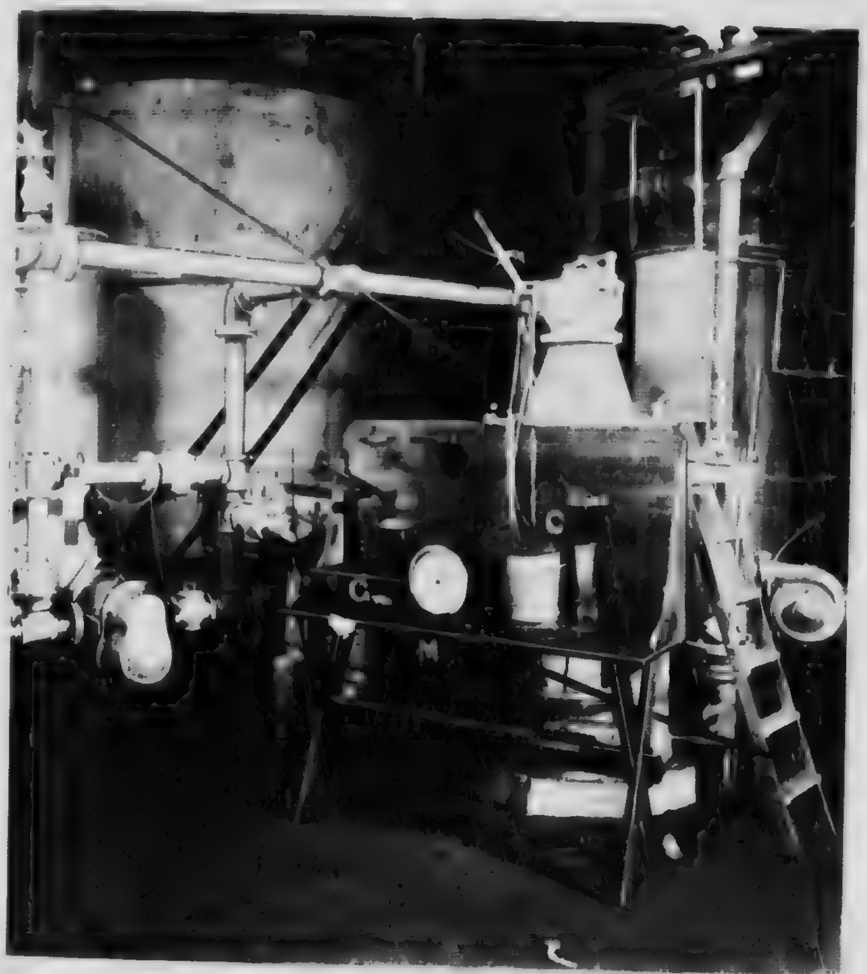


[illegible] arrangement of experimental producer gas plant



gas plant Department of Mechanical Engineering, Me

Plate XLIX



Boys' gas calorimeter as set up for producer tests. Department of Mechanical Engineering, McGill University.

Fairbanks standard scales were used for coal and ash weighing. Water used by the scrubbers and gas washer was metered.

Plate I. shows the interior of the producer house, with the engine ke, gas holder, and dry scrubber, the view being taken from the east end. The view from the west end is given in Plate II. In this photograph will be seen the suction producer **P**, with its starting fan **F**, and wet scrubber **W**, the sawdust scrubber **S**, the exhauster **E** with its by-pass, the gas holder **G**, the dry scrubber **D** and the gas meter **M**.

METHODS OF CONDUCTING TESTS AND MAKING MEASUREMENTS LOG AND CALCULATIONS FOR ONE TRIAL

GENERAL PLAN OF TESTS

As in the case of the boiler trials reported in Part VII, the object of the work was to compare the behaviour of, and the economic results obtained from, various samples of Canadian fuel; for this purpose only enough material was available for one run with each coal, including a reasonable preliminary period for adjusting the working conditions at the beginning of the test. In one or two cases, however, it was found possible to make longer tests or repeat tests, and these are duly recorded. In order to obtain more complete information as to the characteristics of each coal, it would have been desirable to make a series of three or four tests with each fuel, but the expense and time involved rendered such a course quite impossible. The length of continuous run necessary to obtain a close measurement of coal consumption in a gas producer test (under ordinary conditions as to rate of combustion) is at least 100 hours, if the result is to be correct within less than 2½ per cent,[1] and a complete series of tests of this length could not be carried out with the staff or in the time assigned for the work. With the shorter tests actually made a high degree of accuracy in the measurement of coal consumption is not claimed, but the judgment on the performance of a coal in a gas producer depends not only on this quantity but also on such practical details as the amount of labour required in handling the coal and refuse, the uniformity or quality of the gas produced, and the trouble experienced with tar or dirt, points on which a 24 hour run gives sufficient information. The behaviour of each coal in these respects was carefully observed.

It may be noted that the preliminary period above mentioned was found in practice to be too short, and it is, therefore, certain that many of the coals tested could have been utilized to better advantage than was actually the case. For example, three of the samples were large enough to make repeat tests under somewhat different conditions from those obtaining in the original trials; with two of these samples the second test gave much better results than were reached in the original tests; in the third case (a lignite) the fuel had apparently altered by keeping.

In the circumstances, it was decided that in each case a continuous run of 24 hours should be aimed at, with a preliminary period of from 4 to 5 hours, during which the best available working conditions for the fuel un test should, if possible, be found; the proper depth of fuel bed and amoun be supplied being determined during this time and before ment of the trial proper. In one case, by mixing the remaind samples of somewhat similar coal, it was found possible to m a run of 100 working hours, working 10 hours per day and banking the p ducer at night. This test was made chiefly to demonstrate the capacity the installation for work under conditions similar to those of comme practice, and as a check on other tests in the same group

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[1] See p. 68.

The unavoidable delay in the installation of a satisfactory produce bituminous coals left so short a time available for the whole series of that two had to be made each week during the period from November to March 1909, and this programme was duly carried out, with the excep of an intermission at Christmas. It was thought desirable to clea the producer completely after finishing the work with each coal, in order information might be obtained not only from the analysis of the refuse w drawn during each test, but also from the composition of the fuel bed as d when each trial was completed. As will be seen, the results of these ana were of considerable utility, and the adoption of this system (as comp with the method of continuous running or banking fires between the rendered it certain that no material from previous tests remained in producer, and that each fuel received exactly the same treatment so f starting and stopping the tests were concerned. The actual running p for each coal (except where otherwise stated) was about 30 hours, duri about 26 to 28 hours of which the engine was working as nearly as possib at its intended load.

During all tests it was desired to produce gas which would give 30 B.H.P at the engine, but owing to difficulty in working and the necessity for the us of large amounts of steam some of the coals yielded a poor gas and a output. As different fuels gave gases of different calorific values, th volved working at somewhat different rates of combustion, as in the the boiler tests

Duties of Staff.[1]—The available operating and observing staff w sufficiently numerous to work in two complete shifts. It was, howev possible to arrange that the men whose duties were most laborious be relieved at least once during each thirty hour run. Four men w duty at a time: their work was as follows:

Operator No. 1. (In charge of operation of plant.) Atte working of engine, producer, and auxiliary machinery, took counter r directed charging fuel into, and removal of ashes from, the produce

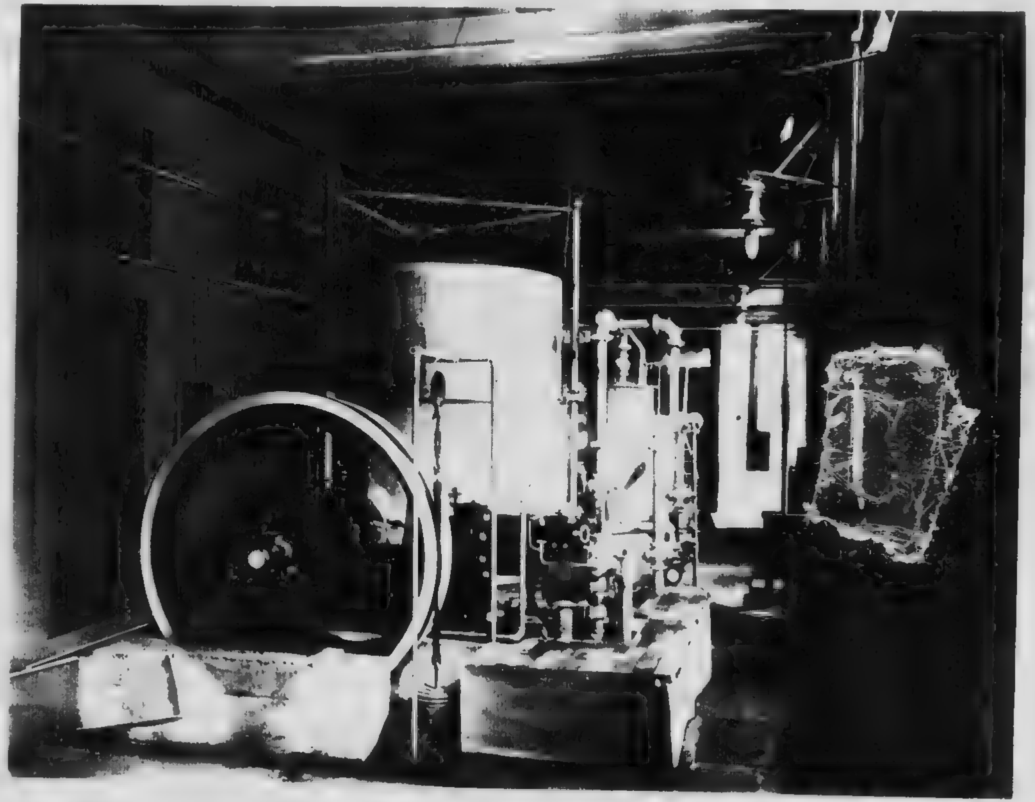
Operator No. 2. (Fireman.) Charged coal into produce ashes, worked fire in producer, collected tar for weighing.

Observer No. 1. Weighed coal, observed pressures, temperat load on brake, took meter readings and indicator diagrams.

Observer No. 2. Worked gas calorimeter and sampled gas for analysis.

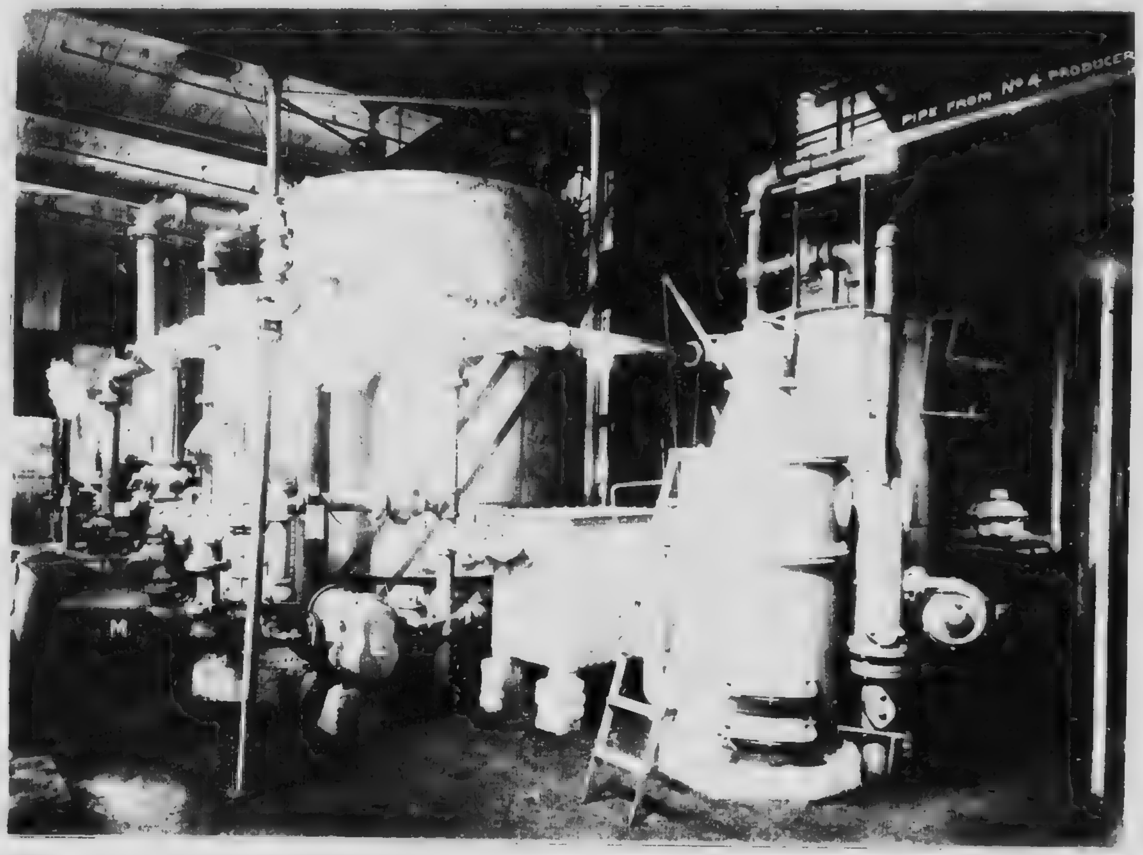
[1] See Vol. I, p. 4 and 5.

Plate I



Interior of gas-producer laboratory, looking west. Department of Mechanical Engineering, McGill University.

Plate 11



Interior of gas-producer laboratory, looking east. Department of Mechanical Engineering, McGill University

These observers interchanged duties occasionally, as was found convenient.

In addition to the above duties, one member of the chemical staff was continuously engaged in making analyses of gas, fuel, and refuse samples. Observations were taken at 30 minute intervals.

General Precautions.—The producer and tar boxes were cleaned out after each trial to ensure that no clinker, tar, or refuse from one trial should be charged to the next. All pipes and joints were tested for leaks periodically. No trial was begun until the engine had been carrying its load satisfactorily for a sufficient period to ensure good working conditions in the fuel bed. The engine valves were not cleaned before each trial, but were taken off when attention was needed, usually after about 60 to 120 hours running. The main gas meter and the calorimeter gas meter were calibrated at intervals of about a week. Coke in scrubbers was renewed once during the series. Scales were tested with standard weights before and after the series.

METHOD OF HANDLING FUEL AND STARTING AND STOPPING TRIALS.

The producer having been cleaned, the space above the grate was filled up to the level of the bottom of the gas outlet (see Fig. 45) with clean broken bricks, free from dust, and of such size that it would pass through the grate when shaken; about 800 pounds were usually required for this purpose, the amount depending on the size and dryness of the pieces. The fire was then started with about 50 pounds of wood and 100 to 150 pounds of screened gas coke, air being admitted from the grate and the products of combustion exhausted by the small fan (Fig. 47). The coal to be tested was then charged until the proper depth of fuel bed was reached and the fire was well alight, when the producer was put on down-draft. As soon as good and uniform gas was obtained at the producer, usually about one to two hours after lighting up, the exhauster was started and the small exhausting fan stopped, the gas being then discharged to the gas holder and thence to the atmosphere. The engine was started and load put on at a convenient time thereafter, and meanwhile the steam supply was adjusted in accordance with preliminary calorimeter determinations. After running thus for a period of from three to five hours, and when constant conditions were obtained, the trial was commenced; at the same time all ash and refuse were cleaned out from the water-seal and any broken brick and ashes brought down by shaking the grate or poking were removed and put aside. Owing to the arrangement of the producer bottom, and to the necessity (with some coals) of poking unequally in different parts of the producer bed, it was usually found that some of the refuse formed during the early part of the run would come through the grate before all the brick had passed. Some of the brick woud then come through during the trial. The carbonaceous refuse (excluding brick) coming through during the test was put aside, weighed, and sampled. During the trial weighed amounts of coal were added to the producer and corresponding amounts of refuse removed at as regular intervals as possible, but it was found that with a coal which gave any trouble from clinker or hanging of the fuel bed, the regular rate of charging coal had often to be departed from to make up the effect of poking. The same circumstances rendered it impossible maintain an absolutely constant depth of fuel, and in many trials the dep varied some inches; it was, however, brought back to the end of the tr as nearly as possible to the original depth. Fortunately, the open producer enabled a very close measurement of the fuel level to be made.

At the conclusion of each test the whole contents of the producer w removed as quickly as possible through the water-seal. An endeavour made at first to keep separate the portion below the gas outlet, in order estimate the combustible value therein, but this was found to be imposs and the attempt was abandoned. The contents of the producer, freed fr any brick by hand picking, were weighed wet, a known proportion, say [illegible] pounds, was then taken, dried, weighed again, and sampled for analysis. The same treatment was accorded to the refuse withdrawn during the test I may be noted that in the first three trials of the series (Nos. 8, 9, and 10) the refuse withdrawn during the trial was inadvertently mixed with the producer contents; for these trials, therefore, it is not possible to give the composition of the refuse formed during the test (See Table XXXIII, Part VIII.)

The coal for each trial was delivered to the gas producer laboratory by the staff in charge of the coal sampling, each bag being tagged with the serial number of the coal (See Column 2, Table XXXIII.) All coal for the gas producer tests was freed from dust before delivery to the producer laboratory by passing over a ½" screen, but beyond this received no special treatment. Coal samples during the trial were taken from each bag, for check analyses, and especially for moisture determinations.

TEMPERATURES, PRESSURES, AND OTHER DETAILS OF TEST.

Steam Supply.—The steam supply was taken from a well lagged pipe carrying about 80 pounds pressure per square inch, and after going through a separator, reducing valve, and gauging orifice, was admitted as required to the ring inlet pipe surrounding the opening at the top of No. 4 producer. The pressure gauges at the gauging orifice were tested periodically, and the gauging apparatus was calibrated by allowing it to discharge under as nearly as possible working conditions into a surface condenser from which the discharge was weighed. The amount of steam passed by the orifice with a given readings of the two pressure gauges was thus determined.

Temperatures.—The temperature of the gas leaving the producer was taken by a thermo-junction electrical thermometer, the indications of which were used as a guide in operating the producer. Gas temperatures at the points were taken with standard mercurial thermometers, as was also the temperature of the warm jacket water of the engine, the latter serving as a general indication of the satisfactory and uniform operation of the engine

Pressures.—The differences of pressure existing between the atmosphere and the interior of the gas main were taken by means of ordinary U water gauges at the following points, and, during regular running, had approximately the following values:

Pressure leaving gas meter and entering gas holder . . . . 3" to 3½" of water

Pressure entering gas meter.	1¼ to 1¾	ins. of water
Pressure leaving exhauster	1½ to 5	" "
Suction entering exhauster	6 to 7	" "
Suction leaving gas washer	5¼ to 6¼	" "
Suction entering gas washer	3½ to 4	" "
Suction leaving wet scrubber	3¼ to 3¾	" "
Suction leaving producer	1¼ to 1¾	" "

The resistance of the fuel bed was thus usually from 1" to 2" of water that of the wet scrubber about 2", that of the gas washer about 2", and that of the meter about 1¼"; the exhauster took about 2½ H.P. and worked against a total difference of from 10" to 14", depending on the conditions of the pipes, passages, scrubber, and producer, and the volume of gas dealt with.

Gas Meter.—As already stated, this was of the standard Westinghouse oil-sealed type; it was calibrated after every four trials by comparing its indications with those shown by the rise of the gas holder whose capacity had been carefully determined. The error in every case was found to be insignificant.

Gas Calorimeter.—This was of the Boys' type (see Plate XLIX, and Part IX), and was calibrated by the chemical staff before being set up in the laboratory. During the progress of the tests, in order to guard against errors due to the effect of tar and dirt on the pressure regulator and calorimeter gas meter, these were cleaned frequently and the meter checked by passing through it a known volume of air from an aspirator bottle.

Fuel, Refuse, and Gas Analysis. The methods of chemical analysis and the apparatus employed are fully discussed in Part IX, and, therefore, need not be dealt with here

Gas Sampling. Gas samples were collected over water in bottles holding about 300 c.c. These were sealed with paraffin wax, labelled, and sent to the chemical laboratory for analysis

Collection and Measurement of Tar.—The series of tests commenced with the western lignites, to which the down-draft producer seemed well suited, practically no tar being found in the gas as it left the producer. With these coals, in fact, the scrubber seemed to take little or no tar out of the gas, and the same remark applies to the gas washer, and in some trials with these coals the latter apparatus was not used at all. When bituminous coals began to be used, however, it was found that while the scrubber and tar washer were certainly cleaning the gas, but little tar was found in the water seals into which their discharges flowed. Steps were taken, at once, therefore, to devise a settling box in which the tar could be more completely separated from the washing water, and after some experiments satisfactory tar boxes were made and placed in service in 1909. In trials made before that date, therefore, figures as to tar are not so complete as in the later tests. The use of steam in the pipes was found a considerable aid in the collection of tar after a test, and in some cases with very sticky tar it was necessary to by-pass the gas washer and clean it out with a steam jet before starting it again.

Measurement of Water Used. The water used by the wet scrubber metered, and taken from the city mains. That used by the gas washe estimated from the results of a series of special experiments. No partic attempt was made to economize in the use of water.

Engine Measurements. The engine brake horse power was mea by a rope brake (seen in Plate I) in which a dead weight was kept ing between stops. The load on the slack side of the rope was measured spring balance. Revolutions and ignitions were taken by two Crosby co connected to the valve shaft and the governor gear respectively, and more readings were taken every hour, chiefly as a check on the satisfactory ing of the engine, by a Crosby gas engine indicator. It must not be for that the tests were really on the gas producer, the engine being run to de strate the suitability of the gas for power purposes rather than as a p the coal test. In some of the earlier trials when working with free bu coals and especially if gas of low calorific value resulted, it was found d to regulate the working of the producer so as to avoid making rather gas than the engine could take at its regular speed, even when firing ively. In such a case the whole of the gas produced was, of course, me but a small amount passed to the atmosphere through the relief valve in of to the engine. Allowance was made for this in the calculation B.H.P., by taking the B.H.P. as that which would have maintained had all the gas metered been sent to the engine, the consumption per B.H.P per hour with approximately the same load known from a period during which all gas metered had passed th the engine. In later trials, when the staff were more familiar w operation of the producer, this trouble did not arise.

DETERMINATION OF RATE OF FUEL CONSUMPTION

This quantity, as distinguished from the rate at which coal is c into the producer, is perhaps the most difficult to establish accurately certainly the most important in a gas producer test.[1] The various p methods of determining the actual rate of fuel consumption have a been discussed. It was hoped that in working out the results of th here reported, the fuel actually consumed could have been closely est from the coal charged, by the aid of data derived from the c analyses of the gas produced, the refuse removed during the trial, contents of the producer at the conclusion of the trial. This was fel especially desirable, because the length of each trial was limited to 24 and any difference in condition of fuel bed, as between the beginni end of a trial, would, therefore, have a comparatively large influenc apparent value of the producer efficiency.

On proceeding to work out the trials in this manner, it was fou in certain of the trials somewhat inconsistent results were obtained, alt in most cases a fair agreement was found with the known amounts of dealt with and the fuel bed conditions which probably existed. It was there-one, considered better to state only the coal actually charged, using the analyses of the refuse and producer content samples as an indication of the similarity or otherwise of fuel-bed conditions at the beginning and end of the trial. This has been done in discussing the trial results on subsequent pages.

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[1] See p 67.

DETAILED RESULTS OF PRODUCER TRIAL No. 32

In order to exemplify the methods adopted and the observations taken during the gas producer tests, the log and observation sheets for one trial, No. 32, are attached, together with the [illegible] calculations worked out in [illegible]. This test was made on a sample of [illegible] coal from Cape Breton, and is here given as [illegible] representative one, [illegible] the same coal as that [illegible]. The complete calculations are [illegible] of the boiler tests.

Similar detailed information as to the log and observation sheets of the [illegible] series of trials is given in Volume V of this report.

Log of Events.

Trial of No. 1 producer with No. 36 coal.
Date March 8 and 9, 1909. Trial number 32.
Observations of general conditions.
Observers: J. S. Cameron and G. Killam.

General Notes.

Barometer at beginning	29·83 inches
" " 8.20 p.m.	29·88 "
" " end	29·97 "
mean	29·89 "
Water meter 9 a.m.	96877 imp. gallons
Water meter 8 a.m.	99765 imp. gallons
Difference	2888 imp. gallons in 23 hours
[illegible] in producer base	935 lbs.

Average level of coal surface below top plate of producer, 17".

2.40 a.m.	March 8	Fire lighted. Charged 5 lbs. shavings, 40 lbs. wood, 120 lbs. coke.
3.20 "	"	Down draft. Charged 131 lbs. coke.
4.30 "	"	120 lbs. coke.
5.40 "	"	100 lbs. coal.
7.00 "	"	100 lbs. coal.
8.15 "	"	Started engine. Full load applied.
8.20 "	"	Trial commenced.
11.30 "	"	Cleaned regulator of calorimeter and steamed gas washer.
1.00 p.m.	"	Steamed gas washer.
5.20 "	"	Gas washer running hot. Stopped and passed gas through dry scrubber.

6.20 p.m. March 8. Started gas washer, but trouble continued; stopped it again for remainder of trial.

8.20 a.m. March 9. Trial finished. Drew fire. Engine valves in good order except for a little soot. [illegible] suction during early morning due to [illegible] long pipe.

Summary of Observations.

Date, March 8 and 9, 1909. Producer No. 1 at McGill University.

Time of lighting up 2.40 a.m. Trial commenced 8.20 a.m. to 8.20 a.m.

Duration of trial 24 hours. Kind of fuel, coal No. 36.

Observers and staff during trial: Killam, Cameron, Gardner.

Computers: Killam, Cameron, Ford.

Chemists: Stansfield, Nicolls, Campbell.

Fuel—

1.	Total coal charged during trial	lbs. [illegible]
2.	Moisture in coal as charged ..	[illegible]
3.	Calorific value of coal as charged, per lb.	B.T.U. [illegible]
4.	Calorific value of dry coal per lb.	B.T.U. [illegible]
5.	Proximate analysis of coal as charged (by weight): fixed carbon 57·6; volatile matter 35·0; ash 5·0; moisture 2·4%	
6.	Combustible in dry refuse removed during trial: fixed carbon 38·1; volatile matter 4·7%.	
7.	Average depth of fuel bed (measured from centre of gas outlet).	[illegible]

Gas—

8.	Total gas produced during trial (from meter readings).	cub. ft. [illegible]
9.	Average temperature of gas leaving producer	[illegible]
10.	Average temperature of gas at meter. .	[illegible]
11.	Average temperature of air in producer house . .	[illegible]
12a.	Average higher calorific value of gas per cub. ft. by calorimeter (as observed). . .	B.T.U. [illegible]
12b.	Average higher calorific value of gas per cub. ft. by calorimeter (gas dry at 60° and 14·7 lbs. per sq. in.).	B.T.U. [illegible]
13.	Average lower calorific value of gas per cub. ft. by calorimeter (gas dry at 60° and 14·7 lbs. per sq. in.). .	B.T.U. [illegible]

14	Average barometric pressure	sq. in. 14.65
15	Average suction at producer	ins. 0.98
16	Average suction at exhauster	ins. 9.40
17.	Average pressure of gas at meter	ins. 1.62

am, Water, Etc.

18	Total steam used in producer during trial ..	lbs. 2160
19	Total water used in scrubber and gas washer	lbs. 35940
20	Total tar extracted in scrubber and gas washer	lbs. 94
21	Average power required to drive exhauster .	H.P. 2.5
22	Average power required to drive gas washer	H.P. 1.5

Engine

23.	Total revolutions during trial (from counter) . .	320198
24	Total explosions during trial (from counter) .	145794
25.	Average effective load on brake. .	lbs. 155.5
26.	Effective radius of brake wheel .	ft. 3.836
27.	Average mean effective pressure from indicator diagrams .	lbs. sq. ins. 69.6

28. NOTES. Fire poked at: 8.20, 8.50, 9.20, 9.40, 9.55, 10.50, 11.15, 11.55 a.m., 12.05, 12.45, 1.05, 1.45, 2.40, 3.50, 4.50, 5.05, 7.40, 8.30, 10.50, 11.40 p.m., 2.40, 4.40, 5.40, 6.25 a.m.

Refuse removed at: 8.50, 9.55 a.m., 12.45, 2.45, 5.25, 8.30 p.m., 2.30, 3.50, 5.40 a.m.

Behaviour of coal: required considerable attention — cakes.

Average time between poking: one hour.

Clinker: little trouble. Tar: a good deal.

State of engine valves at end of trial: good condition except for a little soot.

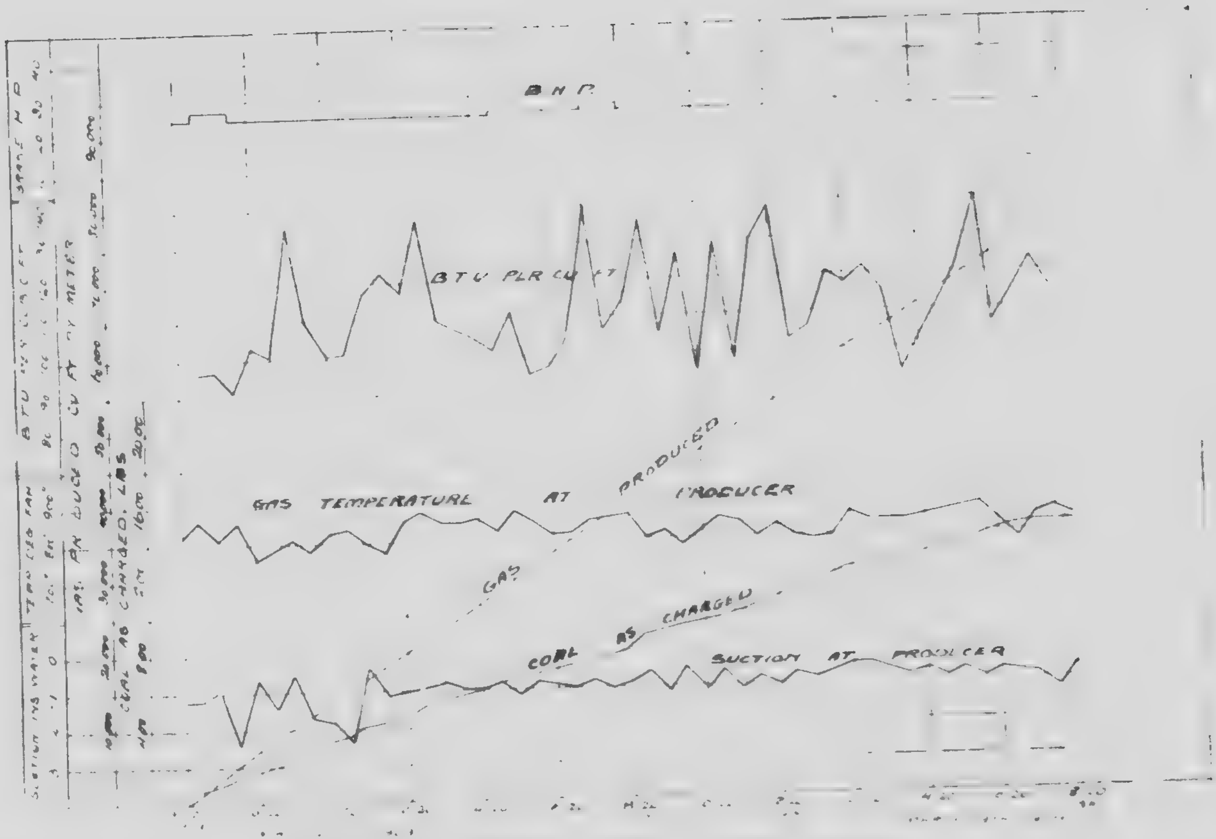
Valves last cleaned: February 23, 1909.

29. ANALYSIS OF DRY COAL.	
Hydrogen .	5.0
Carbon . .	76.7
Nitrogen . .	
Oxygen. .	
Sulphur .	2.4
Total carbon contained by dry coal 1085 lbs.	

30. ANALYSIS OF GAS BY VOLUME.	
Carbon dioxide .	10.9
Oxygen. .	0.5
Carbon monoxide .	11.4
Hydrogen. .	11.4
Methane	3.2
Ethylene.	0.1
Nitrogen. .	62.5

Remarks.

A satisfactory trial considering the nature of the coal. A rather deep fire bed was maintained which destroyed a good deal of the tar. This coal gives some trouble in the producer but the gas was uniform enough to avoid any engine trouble.



PRODUCER TRIAL N[illegible] 32. COAL [illegible]

Summary of Results

Quantities.

51	Dry [illegible]	[illegible]
52	Combustible [illegible]	[illegible]
53	Average B.H.P. [illegible]	H.P. [illegible]
54	Average [illegible] H.P. [illegible]	H.P. 10[illegible]
55	Average H.P. [illegible]	H.P. [illegible]
56	Average B.H.P. [illegible]	H.P. 2[illegible]
57	Average B.H.P. [illegible]	H.P. [illegible]
58	Average B.H.P. [illegible] produced [illegible]	H.P. [illegible]

(b) Quantities.

59	Coal [illegible]	[illegible]
60	Dry coal [illegible]	[illegible]
61	Combustible [illegible] per [illegible]	
62	Coal charged per [illegible]	[illegible]
	Dry [illegible]	[illegible]
	Combustible [illegible]	[illegible]
	Coal [illegible] used in producer	[illegible]
[illegible]	Coal [illegible] used in producer	[illegible]
[illegible]	Gas by meter supplied by producer per hour	[illegible] 3502
[illegible]	Gas dry at 60° and 14·7 lbs. [illegible] supplied by producer per hour	[illegible] 3220
[illegible]	Gas by meter supplied [illegible] per hour while gas consumption was taken	c. ft. 3502
	Gas dry at 60° and 14·7 lbs. per sq. in. supplied to engine per hour while gas consumption was taken	c. ft. 3220
[illegible]	Calorific value of coal charged per hour	B.T.U. 817000
[illegible]	Calorific value of gas produced per hour (lower value)	B.T.U. 342930
[illegible]	Steam used in producer per hour	lbs. 90·4

(c) [illegible] Results.

[illegible]	Gas dry at 60° and 14·7 lbs. per sq. in. produced per lb. of coal charged	c. ft. 73·3

55. Gas (dry at 60° and 14·7 lbs. per sq. in.) produced per lb. of dry coal charged . . . cub. ft. 5[illegible]

56. Gas (dry at 60° and 14·7 lbs. per sq. in.) produced per lb. of combustible charged . . . cub. ft. 57·6

57. Gas (dry at 60° and 14·7 lbs. per sq. in.) used per I.H.P. per hour. cub. ft. 7[illegible]·9

58. Gas (dry at 60° and 14·7 lbs. per sq. in.) used per B.H.P. per hour. . . cub. ft. 12[illegible]·7

59. Steam used in producer per lb. coal charged . lbs. 1·4[illegible]

60. Water used in scrubber and gas washer per lb. coal charged . . . . . . lbs. 2[illegible]·77

61. Water used in scrubber and gas washer per 1,000 cub. ft. gas produced . lbs. 453·5

62. Efficiency of process of gas production and cleaning based on coal charged 0·42

63. Efficiency of producer plant allowing for power used for auxiliaries. . . . . . 0·37

64. Efficiency of producer plant allowing for power used for auxiliaries, and for steam used in producer. . 0·30

65. Thermal efficiency of engine based on B.H.P. 0·187

66. Over all efficiency of producer and engine plant. 0·078

67. Calorific value of gas supplied to engine per B.H.P. per hour . . . . B.T.U. 13600

68. Calorific value of coal charged into producer per B.H.P. per hour . . . . B.T.U. 3245[illegible]

	Coal as charged	Dry coal	Comb[illegible]
69 Pounds per hour charged into producer per B.H.P. developed by engine .	2·40	2·34	2·22
70 Pounds per hour charged into producer per B.H.P. allowing for power used by auxiliaries	2·85	2·78	2·64
71 Pounds per hour charged into producer per B.H.P. allowing for power and also for steam used by producer	3·37	3·29	3·12

TABLE XXIX.

Observations of Composition of Gas by Volume.

Trial of No. 4 producer with No. 36 coal.
Date, March 8 and 9, 1909. Trial number—32.
Observer: (Chemist) W. B. Campbell.

NOTES. R.B. apparatus used. Samples taken on pressure side of exhauster.

Sample No.	Time of sampling	Amt. taken c.c.	Carbon dioxide	Oxygen	Ethylene	Carbon monoxide	Methane	Hydrogen	Nitrogen	Inflammable gas %
	a.m.									
1	9·05	100	8·9	0·8	0·3	8·6	4·4	11·7	65·3	25·0
2	10·00	100	9·7	0·5	0·1	14·4	3·2	10·4	61·7	28·1
3	11·00	100	9·1	0·6	0·0	13·4	2·6	7·5	66·8	23·5
4	12·00	100	10·0	0·5	0·2	8·4	4·2	9·8	66·9	22·6
	p.m.									
5	1·00	100	10·0	0·3	0·0	13·9	2·5	4·1	69·2	20·5
6	2·00	100	10·9	0·4	0·1	10·0	3·2	7·6	67·8	20·9
7	3·00	100	12·3	0·2	0·2	10·4	3·3	14·4	59·2	28·3
8	4·00	100	12·9	0·3	0·0	11·6	2·0	14·4	58·8	28·0
9	5·00	100	13·7	0·2	0·0	10·4	2·9	12·2	60·6	25·5
10	6·30	100	10·6	0·7	0·0	13·3	2·7	11·8	60·9	27·8
11	8·00	100	10·7	0·5	0·2	12·7	3·1	9·8	63·0	25·8
12	9·30	100	10·3	0·6	0·0	15·1	2·5	9·6	61·9	27·2
13	10·50	100	8·8	0·6	0·4	11·2	4·4	16·0	58·6	32·0
	a.m.									
14	12·30	100	10·3	0·5	0·0	10·7	3·6	13·2	61·7	27·5
15	1·50	100	12·0	0·8	0·0	10·1	2·8	14·4	59·9	27·3
16	3·50	100	12·4	0·5	0·0	12·8	1·9	9·7	62·7	24·4
17	4·50	100	13·4	0·7	0·0	10·1	2·4	14·4	59·0	26·9
18	5·50	100	10·8	0·7	0·3	8·7	5·6	14·3	59·6	28·9
19	6·50	100	10·1	0·6	0·1	9·9	4·2	10·9	64·2	25·1
	Averages......		10·9	0·5	0·1	11·4	3·2	11·4	62·5	

TABLE XXX

Observations of Gas Meter and B. H. P.

Trial of No. 4 producer with No. 36 coal.

Date, March 8 and 9, 1909. Trial number—32.

Observers: J. S. Cameron and G. Killam.

NOTES.—All gas produced was taken by engine, relief valve on [illegible] holder remained closed throughout trial.

Time	Main gas meter reading	Cub. feet in interval	Cub. feet Total gas by meter	Loads on tight and slack side of brake		Net load on brake	Revolution counter reading (on side shaft)	Exp[illegible] counter reading
				lbs.	lbs.	lbs.		
a.m.								
8.20	2430300	......	......	250	100	150	060961	06408[illegible]
8.50	2432190	1890	1890	275	110	165		
9.20	2433890	1700	3590	275	110	165		
9.50	2435710	1820	5410	250	100	150		
10.20	2437355	1645	7055	250	100	150		
10.50	2439080	1725	8780	250	100	150	077700	079[illegible]
11.20	2440990	1910	10690	250	100	150		
11.50	2442130	1140	11830	250	100	150		
p.m.								
12.20	2443800	1670	13500	250	100	150		
12.50	2445500	1700	15200	250	100	150		
1.20	2447240	1740	16940	250	100	150		
1.50	2448700	1460	18400	250	100	150		
2.20	2450240	1540	19940	250	100	150		
2.50	2451985	1745	21685	250	100	150		
3.20	2453540	1555	23240	250	100	150		
3.50	2455070	1530	24770	250	100	150		
4.20	2456900	1830	26600	250	100	150		
4.50	2458685	1785	28385	250	95	155		
5.20	2460310	1625	30010	250	95	155		
5.50	2462080	1770	31780	250	95	155		
6.20	2463845	1765	33545	250	95	155		
6.50	2465460	1615	35160	250	95	155		
7.20	2467280	1820	36980	275	108	167		
7.50	2468765	1485	38465	275	108	167		
p.m.								
8.20	2470550	1785	40250	250	95	155		
8.50	2472220	1670	41920	250	95	155		
9.20	2473750	1530	43450	250	95	155		
9.50	2475355	1605	45055	250	95	155		
10.20	2477080	1725	46780	250	95	155		
10.50	2478960	1880	48660	250	95	155		
11.20	2480430	1470	50130	250	95	155		
11.50	2482160	1730	51860	250	95	155		
a.m.								
12.20	2483740	1580	53440	250	85	165	168030	161570
12.50	2485340	1600	55040	250	85	165		
1.20	2486790	1450	56490	250	85	165		
1.50	2488500	1710	58200	250	85	165		
2.20	2489950	1450	60650	250	85	165		
2.50	2491550	1600	61250	250	85	165		
3.20	2493220	1670	62920	250	95	155	187940	179[illegible]
3.50	2494980	1760	64680	250	95	155		
4.20	2496760	1780	66460	250	95	155		
4.50	......	......	......	250	95	155		
5.20	2499900	3140	69600	250	95	155		
5.50	2501500	1600	71200	250	95	155		
6.20	2503200	1700	72900	250	95	155		
6.50	2504660	1460	74360	250	95	155		
7.20	2506240	1580	75940	250	95	155		
7.50	2507910	1670	77610	250	95	155		
8.20	2509540	1630	79240	250	95	155	221060	[illegible]9877

TABLE XXXI

Observations of Gas Calorimeter and Coal Weighed

Trial of No. 4 producer with No. 36 coal.

Date, March 8 and 9, 1909. Trial number 32.

Observers: J. S. Cameron and G. Killam.

NOTES.—Boys' calorimeter used.

Time	Gas Temp Deg.	Cub. ft. gas	Water Deg. Inlet	Temp. Cent. Outlet	C. C. of water	B.T.U. per cub. ft.	Re-marks
a.m.							
8 20			Regulating Calorimeter				
8 50	59	5/12	6·00	11·58	1810	9	
9 20	58	"	5·57	10·97	1880	96·[illegible]	
9 50	59	"	5·65	10·62	1930	91·3	
10 20	60	1/3	6·05	11·09	1710	102·4	
10 50	60	"	6·09	11·09	1770	105·2	
11 20	59	1/4	6·57	11·87	1600	134·7	
11 50	60	5/12	6·52	12·90	1790	108·7	
p.m.							
12 20	61	1/3	6·25	11·54	1600	100·5	
12 50	61	1/3	6·18	11·45	1710	101·0	
1 20	62	"	6·52	11·60	1910	115·4	
1 50	62	1/2	6·31	15·71	1650	122·8	
2 20	63	5/12	6·55	13·29	1830	117·4	
2 50	63	"	6·70	14·82	1770	136·5	
3 20	63	"	6·96	13·60	1730	109·4	
3 50	64	"	7·45	13·62	1820	106·9	
4 20	64	1/3	7·51	13·01	1600	104·5	
4 50	66	"	11·95	16·77	1770	101·2	
5 20	65	"	7·89	13·18	1770	111·4	
5 50	65	"	8·70	12·98	1870	95·2	
6 20	65	1/2	8·60	15·63	1735	96·6	
6 50	65	"	8·98	16·47	1750	101·0	
7 20	65	"	8·92	19·21	1725	140·5	
7 50	64	5/12	9·35	16·40	1600	107·0	
8 20	64	"	9·37	16·44	1790	111·6	
8 50	63	7/12	9·32	20·33	1830	136·8	
9 20	63	1/2	9·42	17·42	1660	105·2	
9 50	63	"	9·47	18·90	1695	127·4	
10 20	63	"	9·82	16·98	1690	95·8	
10 50	63	"	10·02	20·05	1625	129·0	
11 20	63	"	10·23	17·39	1755	98·7	
11 50	64	"	10·00	19·22	1780	130·0	
a.m.							
12 20	64	5/12	7·59	16·70	1600	138·4	
12 50	63	"	7·29	14·01	1610	102·9	
1 20	63	"	7·02	13·67	1660	105·0	
1 50	63	"	7·09	14·81	1650	121·0	
2 20	63	"	7·05	14·71	1620	118·4	
2 50	63	"	6·27	14·07	1640	121·5	
3 20	64	"	7·48	14·74	1670	115·3	
3 50	64	"	7·31	12·85	1800	94·5 [2]	
4 20	63	"	7·20	12·88	1900	102·5	
4 50	62	"	6·71	13·36	1950	123·0 [3]	
5 50	63	1/3	7·15	14·56	1600	141·0	
6 20	63	1/3	6·97	12·95	1640	106·5	
6 50	63	"	6·99	12·75	1690	115·7	
7 20	63	5/12	7·00	14·06	1850	124·0	
7 50	63	"	7·10	13·80	1840	117·0	

Time	Coal charged	Total Coal	Time of poking	Time removing refuse
a.m.				
8 20	50	50	8 20	
8 50	25	75	8 50	8 50
9 20	25	100	9 20	
9 40	25	125	9 40	
9 55	25	150	9 55	9 55
10 20	25	175		
10 50	25	200	10 50	
11 05	25	225		
11 15	50	275	11 15	
11 35	25	300	11 55	
12 05	25	325	12 05	
12 45	25	350	: 45	12. 45
1 05	50	400	1 05	
1 45	25	425	1 45	
2 10	25	450		
2 15	75	525	2 40	2. 45
3 50	50	575	3 50	
5 05	75	650	4 50	
6 05	50	700	5 05	5 25
7 10	50	750	7 10	
8 10	50	800		
8 40	75	875	8 30	8 30
9 40	50	925		
10 50	50	975	10 50	
11 10	50	1025	11 40	
12 15	50	1075		
12.55	50	1125	12 55	
1 35	50	1175		
2 10	50	1225	2 10	2 10
3 50	50	1275		3 50
4 10	50	1325	4 10	
5 40	50	1375	5 10	5 40
6.25	50	1425	6 25	
7.20	25	1450	....	

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[1] After coaling and poking.

[2] Before coaling.

[3] After coaling.

TABLE XXXII

Observations of Temperatures and Pressures

Trial No. 4 producer with No. 36 coal.

Date, March 8 and 9, 1909. Trial number —32.

Observers: J. S. Cameron and G. Killam.

Time	Temperatures of				Pressure, Inches of water				Suction Inches of water		Stea pressu lbs sq	
					Meter		Exhauster					
Time	Producer outlet deg. F	Gas at meter deg. F	Room deg. F.	Engine cooling water deg. F.	Outlet	Inlet	Outlet	Inlet	Gas washer inlet	Producer outlet	Inlet gauge	
a.m.												
8 20	820	64	60	103	3·7	7·2	7·4	9·2	3·4	1·2	74	70
8 50	840	65	59	143	3·6	7·0	7·2	10·5	4·7	1·2	73	69
9 20	840	65	58	141	3·4	5·7	5·9	7·6	3·4	0·9	70	66
9 50	860	65	61	140	3·7	6·6	6·8	11·0	5·3	2·5	74	70
10 20	760	66	62	138	3·4	5·3	5·5	7·0	3·2	0·7	72	68
10 50	780	66	62	136	3·5	5·8	6·0	8·8	4·4	1·4	74	70
11 20	840	66	62	140	3·0	5·7	5·9	5·8	2·7	0·5	57	53
11 50	780	66	64	137	3·4	5·7	5·9	7·8	4·0	1·7	75	72
p.m.												
12 20	820	70	64	128	3·7	6·6	6·8	10·3	4·8	1·8	72	68
12 50	840	70	64	127	3·6	6·3	6·5	10·7	5·5	2·4	70	66
1 20	800	69	65	128	3·4	5·5	5·7	7·8	3·3	0·6	70	67
1 50	770	68	62	140	3·1	4·6	4·8	7·5	3·7	1·1	70	66
2 20	850	67	63	140	3·4	6·4	6·8	9·5	4·6	1·0	74	71
2 50	880	64	65	139	3·4	6·3	6·5	9·6	4·7	0·9	74	70
3 20	850	67	65	145	3·2	5·4	5·6	8·0	3·7	0·8	73	69
3 50	850	67	67	138	3·6	6·4	6·6	10·4	4·8	1·0	73	68
4 20	860	67	66	140	3·6	6·5	6·7	11·4	4·9	1·0	71	69
4 50	830	68	70	138	3·3	5·3	5·5	7·4	4·0	0·8	65	60
5 20	880	71	67	139	3·5	6·2	6·4	9·8	5·3	1·4	68	64
5 50	850	71	67	138	3·4	6·1	6·3	8·5	4·7	0·8	69	65
6 20	820	70	66	139	3·3	5·3	5·5	8·7	4·6	0·9	70	66
6 50	820	68	65	143	3·5	6·0	6·2	8·8	5·4	1·0	54	50
7 20	850	66	64	144	3·6	6·4	6·6	9·6	4·4	0·8	42	38
7 50	860	66	64	140	3·6	6·7	6·9	9·6	5·4	1·0	78	74
8 20	840	64	63	152	3·4	5·4	5·6	9·2	5·2	0·9	56	64
8 50	800	63	63	141	3·1	5·7	5·9	7·2	3·8	0·6	54	50
9 20	820	63	63	136	3·6	6·6	6·8	9·5	5·5	1·0	55	51
9 50	780	62	63	132	3·0	5·5	5·7	8·0	4·2	0·5	50	45
10 20	820	62	64	132	3·4	6·1	6·3	9·4	5·4	1·0	52	48
10 50	850	62	65	133	3·6	6·6	6·8	8·5	5·0	0·6	52	48
11 20	840	63	65	130	3·6	6·6	6·8	9·9	5·9	1·4	50	46
11 50	800	64	65	135	3·0	5·0	5·2	7·8	4·6	0·8	61	57
a.m.												
12 20	830	64	64	132	3·2	5·3	5·5	9·5	5·4	2·0	55	52
12 50	800	65	64	132	3·3	5·3	5·5	10·0	5·9	0·7	44	40
1 20	790	65	63	133	3·1	5·4	5·3	10·2	6·0	0·8	60	57
1 50	800	65	64	132	3·1	4·8	5·0	7·8	4·7	0·6	50	47
2 20	860	66	65	129	3·3	5·3	5·5	7·8	4·7	0·5	60	56
2 50	840	66	65	130	3·2	5·7	5·9	7·0	4·6	0·5	58	55
3 20	840	66	65	132	3·3	5·4	5·6	8·7	5·2	0·7	65	62
3 50	840	67	66	131	3·4	6·0	6·1	9·4	5·8	0·8	64	61
4 20	850	67	65	130	3·4	6·0	6·1	9·4	6·0	0·7	[illegible]	52
4 50	[illegible]	66	64	128	3·5	6·4	6·3	9·7	6·0	0·9	[illegible]	48
5 20	870	66	64	132	3·2	5·8	6·0	9·5	5·9	0·7	[illegible]	47
5 50	880	66	64	130	3·3	6·0	6·2	9·4	6·0	0·7	[illegible]	50
6 20	820	66	64	132	3·4	6·4	6·8	11·0	7·0	0·9	[illegible]	58
6 50	780	66	64	135	3·2	5·5	5·7	10·0	6·0	1·0	[illegible]	60
7 20	840	66	62	134	3·3	5·5	5·7	12·5	7·0	0·9	[illegible]	55
7 50	860	66	62	131	3·2	5·4	5·5	11·6	7·1	1·2	[illegible]	45
8 20	840	66	63	133	3·4	5·6	5·8	10·9	7·4	0·7	[illegible]	57

Calculations for Trial 32 Leading to Figures Given in Summaries of Observations and Results, pp. 86 to 90.

Item 3. Calorific value of coal as charged, per pound.

This is obtained from Item 4 and from the known amount of moisture in the coal as sampled during the trial and given in Item 5.

Item 4. Calorific value of dry coal per pound.

This was measured directly in each case by the chemical staff. For details of coal calorimeter methods, see Part IX.

Item 12*a*. Higher calorific value of gas per cubic foot by calorimeter (as observed). This was taken directly every 30 minutes during the trial, by means of a Boys' calorimeter.

The average in this case was 112·8 B.T.U. per cubic foot at 63°F. and 1″ of water.

Item 12*b*. Higher calorific value of gas per cubic foot by calorimeter (gas dry at 60° and 14·7 lbs. per sq. inch.)

The average pressure of gas and vapour at calorimeter meter was barometric + 1″ of water. One inch of water being equivalent to 0·0361 lbs. per sq. in., the total pressure of the gas and vapour at calorimeter meter was then

Item 14 + 0·0361 = 14·65 + 0·036 = 14·686 lbs. per sq. in.

From this pressure we must deduct the pressure of water vapour, in order to find the pressure of the gas itself.

From tables (Kent's Mechanical Engineers' Pocket Book, Ed. 1904, p. 184) we find that the pressure of saturated water vapour corresponding to 63° F. is 0·56 inches of mercury or 0·274 lbs. per sq. in.

Hence the gas pressure at calorimeter meter was

14·686 − 0·274 = 14·412 lbs. per sq. in.

And one cubic foot of gas at 60° and 14·7 lbs. per sq. in. becomes

$$1 \times \frac{524}{521} \times \frac{14\cdot70}{14\cdot41} = 1\cdot026 \text{ cubic feet at } 63^\circ \text{ and } 14\cdot41 \text{ lbs. per sq. in.}$$

The higher calorific value of 1 cubic foot of gas dry at 60° and 14·7 lbs. per sq. in. is then

Item 12b = 112·8 × 1·026 = 115·7 B.T.U.

Item 13. Lower calorific value of gas per cubic foot (dry at 60° and 14·7 lbs. per sq. in.)

From observations it appears that in this test the heat given up by condensation of steam formed by the hydrogen in 1 cubic foot of standard gas (at 60° and 14·7 lbs. per sq. in.) was 9·2 B.T.U.

The lower calorific value is then

Item 13 = Item 12b − heat corresponding to condensation of steam
115·7 − 9·2 = 106·5 B.T.U.

Item 19. Total water used in scrubber and gas washer.

From experiment 240 lbs. of water per hour were found to be used in the gas washer, hence during trial 240 × 24 = 5760 lbs. were used.

From observation 28880 lbs. of water were used in the wet scrubber during

23 hrs. of the trial and hence $\frac{24}{23} \times 28880 = 30150$ lbs. were used during whole trial.

Total water used in gas scrubber and washer, therefore, is

$$\text{Item 19} = 5760 + 30150 = 35910 \text{ lbs.}$$

Item 31. Dry coal charged during trial. This is found from the t weight of coal fired, less weight of moisture, and is equal to

Total coal fired (Item 1) × (1 − moisture per lb. coal [from Item

$= 1450\,(1 - 0{\cdot}024) = 1415$ lbs.

Item 32. Combustible charged during trial.

This is found from the total weight of coal fired, and the known comp tion of the coal (Item 5) and is equal to

$$\text{Total coal fired} \times \frac{\%\text{ fixed carbon} + \%\text{ volatile matter}}{100}$$

$$1450 \times \frac{57{\cdot}6 + 35{\cdot}0}{100} = 1450 \times 0{\cdot}926 = 1343 \text{ lbs.}$$

Item 33. Average B.H.P. of engine during trial.

This is found as follows:—

Work done on brake per minute = effective load on brake × effectiv circumference of brake wheel × revolutions per minute

$$= \text{Item } 25 \times 6{\cdot}28 \times \text{Item } 26 \times \frac{\text{Item } 23}{\text{duration of trial}}$$

$$= 155{\cdot}5 \times 6{\cdot}28 \times 3{\cdot}836 \times \frac{320198}{24 \times 60}$$

$= 833500$ ft. lbs.

$$\text{Hence B.H.P.} = \frac{833500}{33000} = 25{\cdot}2$$

Item 34. Average indicated horse-power of engine during trial.

This is found from the work done on piston per minute = area piston mean effective pressure on piston × stroke × number of explosions per min

$$= 113 \times \text{Item } 27 \times 1{\cdot}666 \times \frac{\text{Item } 24}{\text{duration of trial}}$$

$$\text{Hence I.H.P} = \frac{132600}{33000} = 40{\cdot}3$$

Item 35. Taken from ammeter and voltmeter readings on the motors driving the exhauster and gas washer respectively, and given in Items 21 and 22.

$$\text{Item } 35 = \text{Item } 21 + \text{Item } 22 = 2{\cdot}5 + 1{\cdot}5$$
$$= 4{\cdot}0$$

Item 36. Average B.H.P. during time when gas consumption of engine was taken.

Worked out from the readings of revolution counter and load on brake taken during a period in which all gas metered was delivered to the engine and none escaped through the relief valve on the gas holder. In this trial the relief valve remained closed during the whole 24 hours. Items 36 and 37 are, therefore, the same as Item 33.

If, however, (as in some of the trials), gas had been wasted through the relief valve, Item 37 would have been found as follows: choosing a period of at least an hour, during which the engine had taken all the gas produced, the meter readings give Item 49, gas (as metered) supplied to engine per hour; and Item 50 [gas (dry at 60° and 14·7 lbs. per sq. inch) supplied to engine per hour] can be calculated from Item 49 in the manner explained below. In a similar manner Items 47 and 48 are found. Then assuming the gas consumption per B.H.P per hour to remain constant during the trial,

Item 37. Average B.H.P. corresponding to total gas produced.

$$= \text{Item } 36 \times \frac{\text{Item } 48}{\text{Item } 50}$$

$$= \begin{array}{l}\text{B.H.P. while gas consumption}\\ \text{of engine was taken}\end{array} \times \frac{\text{total gas furnished by producer per hour}}{\text{gas per hour supplied while consumption of engine was taken}}$$

Item 38. Average B.H.P. corresponding to total gas produced and available for outside use.

If the exhauster and gas washer had been driven directly by the engine, the plant would have been able to supply an amount of power represented by

$$\text{Item } 38 = \text{Item } 37 - \text{Item } 35$$
$$25{\cdot}2 - 4{\cdot}0 = 21{\cdot}2$$

In this item no allowance is made for power equivalent to steam used by producer.

Item 39. Coal charged per hour.

$$\text{Item } 39 = \frac{\text{Item } 1}{\text{duration of trial}} = \frac{1450}{24} = 60{\cdot}4 \text{ lbs.}$$

Item 40. Dry coal charged per hour.

$$\text{Item } 40 = \frac{\text{Item } 31}{\text{duration of trial}} = \frac{1415}{24} = 59{\cdot}0 \text{ lbs.}$$

Item 41. Combustible charged per hour.

$$\text{Item } 41 = \frac{\text{Item } 32}{\text{duration of trial}} = \frac{1343}{24} = 55{\cdot}9 \text{ lbs.}$$

Item 42. Coal charged per square foot of fuel bed per hour

$$\text{Item } 42 = \frac{\text{Item } 39}{\text{cross section of producer}} = \frac{60{\cdot}4}{4{\cdot}0} = 15{\cdot}1$$

In the same way Items 43 and 44 are found from Items 40 and 41.

Item 45. Coal (as charged) per hour equivalent to power used for auxiliaries.

Item 35 gives the amount of power used for auxiliaries. If this power had been furnished by the engine, the corresponding amount of coal charged would have been

$$\text{Item 45} = \frac{\text{Item 39}}{\text{Item 37}} \times \text{Item 35}$$

$$\frac{60 \cdot 4}{25 \cdot 2} \times 4 \cdot 0 = 9 \cdot 6 \text{ lbs.}$$

Item 46. Coal as charged (per hour) equivalent to steam used.

Here it is assumed that each pound of steam supplied to the produ needs 1000 B.T.U. for its production, and that a boiler efficiency of 60 p cent is possible; hence that each pound of steam corresponds to the co sumption of an amount of coal whose calorific value is $\frac{1000}{0 \cdot 6}$ or 1666 B.T.U

These assumed conditions correspond nearly to the generation of ste at atmospheric pressure from feed water at 180°F. We have then

Coal per hour equivalent to steam used

$$= \frac{\text{lbs. steam used (Item 18)}}{\text{duration of trial}} \times \frac{1666}{\text{Cal. value of coal (Item 3}}$$

$$= \frac{2160}{24} \times \frac{1666}{13520} = 11 \cdot 1 \text{ lbs.}$$

Item 47. Gas (by meter) supplied by producer per hour.

$$\text{Item 47} = \frac{\text{Item 8}}{\text{duration of trial}} = \frac{79240}{24} = 3302 \text{ cub. ft.}$$

Item 48. Gas (dry at 60° and 14·7 lbs. per sq. in.) supplied by producer per hour.

The gas passing through the meter was, of course, saturated with water vapour from the scrubber and washer, and under a total pressure somewhat greater than that of the atmosphere. This pressure is Item 14 + Item 17 The temperature is given by Item 10.

Since 1″ of water corresponds to a pressure of 0·0361 lbs. per sq. inch, the total pressure in the gas main at the meter was

$$\text{Item 14} + 0 \cdot 0361 \times \text{Item 17} = 14 \cdot 65 + 0 \cdot 0361 \times 4 \cdot 62 = 14 \cdot 816$$

lbs. per sq. in.

The pressure of saturated water vapour at a temperature of 66° F (Item 10) is given by tables [1] as 0·647 inches of mercury or 0·317 lbs. per sq. in. Hence the pressure of the dry gas is 14·816 − 0·317 = 14·499 or say 14·50 lbs. per sq. in.

The gas produced per hour, if at 66° F. and at a pressure of 14·70 lbs. per sq. in. instead of 14·50, would have a volume given by Item 47 × $\frac{14 \cdot 50}{14 \cdot 70}$

Further, if the temperature had been 60° F. (521° absolute) instead of 66° (527° absolute) the volume of gas per hour would have been

$$\text{Item 48} = \text{Item 47} \times \frac{14 \cdot 50 \times 521}{14 \cdot 70 \times 527}$$

$$= 3302 \times \frac{14 \cdot 50 \times 521}{14 \cdot 70 \times 527} = 3220 \text{ cub. ft.}$$

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[1] Kent's Mechanical Engineers' Pocket Book, Ed. 1904, p. 484.

Item 49. Gas (by meter) supplied to engine per hour while consumption was taken.

This is evidently obtained from the meter readings taken during a period in which the whole of the gas produced went to the engine (in this case the whole trial may be taken) and in this trial is the same as Item 47.

Item 50. Is obtained from Item 49 by exactly the same method as that used in getting Item 48 from Item 47. Evidently in this case Item 50 3220 cub. ft.

Item 51. Calorific value of coal charged per hour.

$$\text{Item } 51 = \text{Item } 39 \times \text{Item } 3$$
$$= 60{\cdot}4 \times 13520 = 817000 \text{ B.T.U.}$$

Item 52. Calorific value of gas produced per hour.

The calorific value of gas as measured by the calorimeter (Item 12) is not quite the same as that of the gas as it passes through the main gas meter, on account of differences in pressure and temperature. Item 52 is, therefore, to be obtained from the gas produced per hour reduced to 60° and 14·7 pounds per sq. in. (Item 48) and its calorific value (Item 13).

$$\text{Item } 52 = \text{Item } 48 \times \text{Item } 13$$
$$3220 \times 106{\cdot}5$$
$$342{,}930 \text{ B.T.U.}$$

The lower value is used because the engine exhausts at such a high temperature that none of the heat given out in condensation can be utilized.

Item 53. Steam used in producer per hour.

$$\text{Item } 53 = \frac{\text{Item } 18}{\text{duration of trial}} = \frac{2160}{24} = 90{\cdot}1 \text{ lbs.}$$

Item 54. Gas (standard conditions) per pound of coal charged.

$$\text{Item } 54 = \frac{\text{Item } 48}{\text{Item } 39} = \frac{3220}{60{\cdot}4} = 53{\cdot}3 \text{ cub. ft.}$$

Item 55

$$\text{Item } 55 = \frac{\text{Item } 48}{\text{Item } 40} = \frac{3220}{59{\cdot}0} = 54{\cdot}6 \text{ cub. ft.}$$

and

Item 56.

$$\text{Item } 56 = \frac{\text{Item } 48}{\text{Item } 41} = \frac{3220}{55{\cdot}9} = 57{\cdot}6 \text{ cub. ft.}$$

Item 57. Gas (standard conditions) consumed per I.H.P. hour.

$$\text{Item } 57 = \frac{\text{Item } 48}{\text{average I.H.P. corresponding to total gas produced}}$$

$$= \frac{\text{Item } 48}{\text{Item } 37 \times \dfrac{\text{Item } 34}{\text{Item } 33}}$$

$$= \frac{3220}{25{\cdot}2 \times \dfrac{40{\cdot}3}{25{\cdot}2}} = 79{\cdot}9 \text{ cub. ft}$$

Item 58. Gas (standard conditions) consumed per B.H.P. hour.

$$\text{Item 58} = \frac{\text{Item 19}}{\text{Item 36}} = \frac{3220}{25\cdot2} = 127\cdot7 \text{ cub. ft.}$$

Item 59. Steam used in producer per pound of coal charged

$$\text{Item 59} = \frac{\text{Item 18}}{\text{Item 1}} \quad \frac{\text{Item [illegible]}}{\text{Item 39}} \quad \frac{90\cdot4}{60\cdot4} = 1\cdot49 \text{ lbs.}$$

Item 60. Water used in scrubbers and gas washer per pound of c

charged

$$\text{Item 60} = \frac{\text{Item 19}}{\text{Item 1}} = \frac{35910}{1650} = 21\cdot77 \text{ lbs.}$$

Item 61. Water used in scrubbers and gas washer per thousand c feet of gas produced.

$$\text{Item 61} = \frac{\text{Item 19} \quad 1000}{\text{Item 8}} = \frac{35910 \times 1000}{79240} = 453\cdot5$$

Item 62. Efficiency of process of production and cleaning gas, on coal charged

$$\text{Item 62} = \frac{\text{Item 52}}{\text{Item 51}} = \frac{342930}{817000} = 0\cdot42$$

Item 63. Efficiency of producer plant allowing for power used auxiliaries.

Here the B.H.P. available for outside use (Item 38) is 21·2 and the gr B.H.P. (Item 37) was 25·2. The gas expended per hour in producing the 25·2 B.H.P., therefore, had a calorific value.

$$\text{Item 52} \times \frac{\text{Item 38}}{\text{Item 37}} = 342930 \quad \frac{21\cdot2}{25\cdot2}$$

$$= 288{,}400 \text{ B.T.U.}$$

The efficiency required will then be

$$\text{Item 63} = \text{Item 52} \quad \frac{\text{Item 38}}{\text{Item 37}} \div \text{Item 51}$$

$$\frac{288400}{817000} = 0\cdot35$$

Item 64. Efficiency of producer plant allowing for power us auxiliaries and for steam used in producer.

Here the heat expended per hour is the calorific value of coal cha producer (Item 51) + calorific value of coal equivalent to steam used 46 + Item 3), and the efficiency required will be

$$\text{Item 64} = \frac{\text{Item 52} \times \dfrac{\text{Item 38}}{\text{Item 37}}}{\text{Item 51} + (\text{Item 46} \times \text{Item 3})}$$

$$\frac{288400}{817000 + 150000} = \frac{288400}{967000}$$

$$= 0\cdot30$$

Item 65. Thermal efficiency of engine based on B.H.P.

This is taken as the ratio

$$\frac{\text{Work done at the shaft of engine per hour}}{\text{Work corr. to calorific value of gas supplied per hour}}$$

$$\frac{\text{Item } 37 \times 33000 \times 60}{778 \times \text{Item } 52}$$

$$\frac{25{\cdot}2 \times 33000 \times 60}{778 \times 342930} = 0{\cdot}187$$

Item 66. Over all efficiency of producer and engine plant.

This is the ratio

$$\frac{\text{Heat corresponding to gross B.H.P.}}{\text{Heat expended}}$$

$$= \frac{25{\cdot}2 \times 33000 \times 60}{778 \times 13520 \times 60{\cdot}4} = \frac{19{,}900}{635{,}000} = 0{\cdot}078$$

Item 66 can evidently also be found as the product of Items 62 and 65.

$$0{\cdot}42 \times 0{\cdot}187 = 0{\cdot}078$$

Item 67. Calorific value of gas supplied to engine per B.H.P. per hour.

This is evidently Item 58 × Item 13 or $\frac{\text{Item } 52}{\text{Item } 33}$

$= 127{\cdot}7 \times 106{\cdot}5$ or $\frac{342930}{25{\cdot}2}$

13600 B.T.U.

Item 68. Calorific value of coal charged into producer per B.H.P. per hour

This is $\frac{\text{Item } 51}{\text{Item } 33} = \frac{817000}{25{\cdot}2} = 32450$ B.T.U.

Item 69. The figures in line 69 will be respectively

$$\frac{\text{Item } 39}{\text{Item } 33} \qquad \frac{\text{Item } 40}{\text{Item } 33} \quad \text{and} \quad \frac{\text{Item } 41}{\text{Item } 33}$$

$$\text{or} \quad \frac{60{\cdot}4}{25{\cdot}2} \qquad \frac{59{\cdot}0}{25{\cdot}2} \qquad \frac{55{\cdot}9}{25{\cdot}2}$$

or 2·40 2·31 and 2·22 lbs.

Item 70. The coal charged contained 0·976 of its weight of dry coal and 0·926 of its weight of combustible (Items 2 and 5), hence the items in line 70 will be respectively

$$\frac{60{\cdot}4}{21{\cdot}2} \qquad \frac{60{\cdot}4 \times 0{\cdot}976}{21{\cdot}2} \quad \text{and} \quad \frac{60{\cdot}4 \times 0{\cdot}926}{21{\cdot}2}$$

or 2·85 2·78 and 2·64 lbs.

Item 71. The coal per hour including that equivalent to steam used is 71·5 pounds, hence the Items in line 71 will be respectively

$$\frac{71{\cdot}5}{21{\cdot}2} \qquad \frac{71{\cdot}5 \times 0{\cdot}976}{21{\cdot}2} \quad \text{and} \quad \frac{71{\cdot}5 \times 0{\cdot}926}{21{\cdot}2}$$

or 3·37 3·29 and 3·12 lbs.

REMARKS ON GAS PRODUCER TRIALS AND THEIR RESULTS—VALUE OF COALS FOR GAS PRODUCER WORK

A fuel which gives satisfactory results when burnt under a steam [illegible] is not necessarily so suitable for gas producer purposes. The [illegible] value of a coal when used in a power gas producer will depend on

(*a*). The heat efficiency obtainable in the producer, or what proportion of the heat value of the coal [illegible] be obtained in the [illegible] produced.

(*b*). The uniformity in [illegible] gas, and the suitability of the gas for engine use, as evidenced [illegible] from dust and tar, and its [illegible] value.

(*c*). The amount of labour [illegible] to handle the coal and resulting [illegible] and to work the fire in the [illegible]

(*d*). The cost of the co[illegible] the producer house.

The results of the trials [illegible] information from which [illegible] opinion may be formed as [illegible] these items, but have no [illegible] nexion with the fourth [illegible] therefore, only be of use to [illegible] reader in judging of the [illegible] for producer work when they [illegible] taken in connexion with correct data [illegible] the price of coal and the [illegible] labour at the place where it is intended to use the fuel.

TREATMENT AND CONDITION OF COALS WHEN TESTED

The treatment of the various coals before delivery to the producer [illegible] is given in Column 5, Table XXXIII. In general it may be said that [illegible] was passed over a ½" screen before use in the producer, so that [illegible] and dust were not used. This does not apply to the anthracite (No. 2[illegible]) which was a mixture of buckwheat and pea sizes, or to the coal used in [illegible] two long trials, Nos. 16 and 12.

No washed coal was tested in the gas producer as there [illegible] co[illegible]cial justification for such an experiment.

GENERAL RESULTS

The leading figures of the whole series of tests will be found in Table XXXIII (Summary Record of Gas Producer Tests) in which the coals are arranged [illegible] geographical order corresponding to that used in stating the results [illegible] boiler trials.[1] In selecting the coals to be tested in the gas producer [illegible] was thought advisable to choose at least one representative coal from [illegible] group, and this was done so far as the size of the samples permitted. [illegible] be noted, therefore, that not all the coals tried under the boiler were [illegible] in the producer. Fortunately, sufficient of nearly all the lignites was av[illegible] to allow of a fairly complete series of gas producer tests being made with [illegible] fuels.

The remarks in Part VII[2] on the general composition of the coals also apply to the fuels used in the gas producer.

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[1] See Part VII, Table IV.

[2] See p. [illegible]2.

The rate of working of the producer, as judged by the amount of coal actually *burnt* per hour per square foot of cross-section of the producer, probably did not exceed about 16 pounds per hour per square foot in the case of any of the bituminous coals tested. Higher figures than this are given in some cases for the coal *charged* into the producer per hour, but in many of the trials it will be found that owing to difficulty in working the coal, and the consequent necessity for poking, a considerable quantity passed through the producer partially unconsumed. With the lignites higher rates of combustion, up to 20 pounds per hour per square foot, were reached without trouble from clinker.

It was desired to generate gas from each coal at a rate sufficient to enable the engine to develop 30 B.H.P., the engine being easily capable of developing 40 B.H.P. with gas of sufficiently high calorific value. With many of the coals, however, it was either impossible to make sufficiently rich gas, or its quality varied too much to enable this average power to be developed, and it will be seen that while the average B.H.P. through the 24 hours was as high as 34·8 in one trial, in others it fell as low as 25·8. It is probable that if repeat trials could have been made with many of the samples a greater average power could have been maintained with them, and gas of a higher and more uniform calorific power generated. In some few cases it was necessary to limit the output of the producer in order to avoid excessive trouble from clinker. The results thus indicate that with many Canadian coals producers should receive a very conservative rating, and that about 15 pounds per square foot of fuel bed per hour is a rate of combustion which should not be exceeded in estimates of the probable continuous output for a producer of a given size.

It will be noticed that the amount of steam used in most of the trials was from one to three times the weight of coal charged. Of course only a portion of this steam was decomposed by the fuel, and the remainder, by keeping the producer temperature lower than would otherwise have been the case, contributed to the somewhat high percentage of carbon dioxide in the resulting gas, and accounted to a certain extent for the low producer efficiencies attained. The large amount of steam was, however, used purposely because it was felt that continuous operation, only to be obtained if there is no serious trouble from clinker, was the first consideration, compared to which high calorific value of gas must be a secondary matter. There is no doubt that with more experience in handling the coals most of the samples could have been worked successfully with much less steam than was actually supplied.

PRODUCER EFFICIENCY.

In attempting to examine and classify the thirty-two trials whose results are given in Table XXXIII, the question at once arises as to how far differences in producer efficiency (and, therefore, in economic value), as shown by the experiments, are really due to causes inherent in the coals themselves, and to what extent they are accounted for by differences in the method of working the producer and operating the plant during the tests. Since the trials were unavoidably too short for extremely accurate results, some discussion of this point is desirable.

It has already been shown that the rate at which fuel is charged into the producer on a short trial is not the same thing as the rate at which the fuel is consumed. The apparent efficiency of the producer (as based on fuel charged and given in Column 42 of Table XXXIII) is, therefore, influenced by the following considerations:

(*a*). The fuel bed at the end of the trial may be poorer in combustible, and contain more ash and refuse, than was the case at the beginning. If the fuel bed is thus burnt down too much, the apparent efficiency will be too high and the coal consumption too low, since the coal fired is credited with having generated gas which was really obtained by impoverishing the fuel bed. Or, the reverse may have happened, and the apparent efficiency may be lower than the real. Variation in apparent efficiency from this cause has evidently no connexion with the nature of the fuel used.

(*b*). By more or less continuous working of the grate, poking, or disturbance of the fuel bed, refuse containing an undue proportion of carbon or combustible may be passed through the producer. This refuse has, of course, given up the greater part of its volatile combustible constituents, but is replaced by the addition of fresh fuel, in such a way that the combustible charged in a given time is evidently greater than the combustible consumed and actually utilized for gas-generation during the same period.

The necessity for this disturbance of the fuel bed, and consequent waste of fuel, may arise either from the nature of the coal, whose caking and adhesive qualities when heated have caused hanging of the fuel layers, or simply from the small size or improper design of the producer. Since it is hardly ever possible to utilize the combustible value of refuse removed during the working of the producer,[1] the effect in either case is to lower the efficiency.

(*c*). A third source of error in the experimental results is due to the fact that the producer may have been improperly worked, since it is impossible to be certain (with one or two trials only) that the working conditions best suited to each particular coal have been actually attained. Apparent efficiencies will, therefore, in most cases be too low from this cause also.

In order to illustrate this aspect of the series of trials, Table XXXIV (Proportion of combustible in coal, in refuse, and in contents of producer at end of trial) has been prepared, and will be considered in connexion with Fig. 19 in analysing the trial results. For example, it appears from Table XXXIV that in trials 24, 13, 40, 38, and 41 the contents of the producer when drawn at the end of the trial had only from 50 per cent to 60 per cent of the proportion of combustible which was originally contained in the coal as charged, whereas an average value of this ratio for all the trials was about 72 per cent. The fuel bed, then, at the end of the tests enumerated above, was relatively

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[1] Except for banking fires at night, as in the special trials 16 and 42.

TABLE XXXIV

Proportion of Combustible in Coal, in Refuse, and in Producer Contents.

Coal No.	Trial No.	Coal as charged			Fixed carbon in combustible %	Combustible in refuse %	Combustible in producer contents %	Ratio		Efficiency based on coal charged %
		Fixed carbon %	Volatile matter %	Combustible %				b : a	c : a	
				a		b	c			
36	32	57·6	35·0	92·6	62·0	42·8	79·5	0·46	0·86	42·0
35	31	52·6	35·1	87·7	60·0	68·5	73·6	0·78	0·84	40·8
38	34	58·8	32·5	91·3	64·5	75·0	72·4	0·82	0·79	38·5
37	33	52·6	34·2	86·8	61·0	51·2	59·8	0·59	0·69	43·2
12	30	53·2	35·4	88·6	60·0	52·2	70·7	0·59	0·80	49·1
15	21	49·2	35·3	84·5	58·0	62·9	63·8	0·74	0·75	39·8
2	24	56·3	30·9	87·2	65·0	42·1	53·7	0·48	0·61	53·3
8	26	61·6	27·5	89·1	69·0	66·5	71·3	0·74	0·80	39·3
3	23	62·7	24·0	86·7	72·5	57·9	67·7	0·67	0·78	57·8
5	22	59·4	31·4	90·8	65·5	61·8	65·4	0·68	0·72	43·8
10	27	45·0	34·4	79·4	57·0	48·8	64·0	0·61	0·81	48·6
11	29	53·3	32·7	86·0	62·5	55·5	61·5	0·65	0·71	53·4
2040	8	36·7	32·8	69·5	53·0	*	53·0		0·76	57·8
2040	17	32·2	43·3	75·5	42·5	47·8	61·0	0·63	0·80	48·8
42	15	42·8	28·7	71·5	60	37·3	58·0	0·52	0·81	51·4
43	12	44·5	26·6	71·1	62·	53·4	54·2	0·75	0·76	53·4
44	13	47·6	35·2	82·8	57·0	40·6	49·1	0·49	0·59	52·2
45	10	46·0	31·2	77·2	59·5	*	56·7		0·73	56·6
46	11	41·1	30·9	72·0	57·0	34·1	51·2	0·48	0·75	65·7
48	14	51·1	29·2	80·3	63·5	54·1	61·9	0·67	0·77	39·7
Mixed**	16	40·8	31·1	71·9	57·0	49·0	49·1	0·68	0·68	49·5
34	36	56·4	24·4	80·8	70·0	33·4	50·5	0·41	0·62	52·9
29	35	67·8	25·1	92·9	73·0	66·4	60·4	0·71	0·65	45·7
27 and 30	42	64·6	24·8	89·4	72·0	66·0	64·8	0·74	0·72	59·9
26	40	62·7	25·6	88·3	71·0	39·5	43·9	0·45	0·50	67·6
25	37	70·5	15·6	86·1	82·0	61·8	61·6	0·72	0·81	43·4
25	38	70·3	16·7	87·0	81·0	44·7	51·3	0·51	0·59	60·0
23 M	41	77·7	11·4	89·1	87·0	50·6	51·0	0·57	0·57	59·8
22 M	18	47·8	36·2	84·0	57·0	70·4	59·9	0·84	0·61	36·6
22 M	25	46·9	36·9	83·8	56·0	51·4	57·3	0·61	0·68	58·2
18	20	44·5	40·3	84·8	52·5	63·0	72·5	0·74	0·85	51·5
17	19	41·5	39·7	81·2	51·0	71·	60·6	0·88	0·75	39·0

* In these tests the refuse was not analysed separately

** A mixture of coals Nos. 40, 42, 43, 44, and 46 used in this test

poor in combustible, indicating that it was partially burnt out and co
tained less combustible than should have been the case; the fuel consum
tions (given in Columns 36 and 37, Table XXXIII) for the coals used in the
trials (coals Nos. 2, 44, 26, 25, and 23 M) are, therefore, probably too lo
and the efficiencies too high. It is, of course, possible that this impoveris
ment of the fuel bed may also have occurred in some other trials and th
its effect may have been masked by some other condition of the tri
Further, it seems likely that the efficiencies given for the producer for tri
32, 31, 30, 26, 27, 15, 17, 37, and 20 (coals 36, 35, 12, 8, 10, 42, 2040,
and 18) are somewhat too low, because in these cases the fuel bed at the
of the trial appears to have been relatively rich in combustible.

In certain other cases (for instance, trial 18, coal 22 M) a low efficie
was obtained because a large amount of refuse rich in combustible was pas
through the producer. This is evident on comparing trial 18 with trial 25
(made with the same coal). These instances are all discussed in detail
the following notes:

Since the actual composition of the fuel bed at the commencement
any particular trial is unknown, it is impossible to give the exact amou
which the coal charged (as given in Column 31, Table IV), was great
less than the amount really consumed. It will be of interest, howeve
inquire what is the probable maximum value of this difference, an
estimate of this can easily be made.

For example, taking coal No. 36 (Trial 32) for which the log and obs
tion sheets have already been given, we find that the contents of the pro
at the end of the trial contained 79·3 per cent of combustible by we
whereas the original coal contained 92·6 per cent. This correspo
a ratio of 0·857, whereas the average value (for all the tests) of this

$$\frac{\% \text{ combustible in fuel bed at end}}{\% \text{ combustible in coal charged}}$$

was 0·72 nearly. At the end of trial 32, 665 pounds of fuel and ash we
moved, corresponding, therefore, to (0·793 × 665) 527 pounds of co
tible. If the fuel bed at the beginning had been of the same weight
the end, and if we assume that it should have contained 72 per ce
combustible value of the coal as charged, its combustible content wou
been (0·72 × 0·926 × 665) 444 pounds of combustible. The diffe
(527 – 444) – 83 pounds of combustible, corresponds to $\frac{83}{0\cdot926}$ or 90
of coal.

In this case, on the above assumptions the coal charged would be
than the coal actually consumed by about 90 pounds, or the coal consumed
be (1450 – 90) 1360 pounds. The real efficiency, instead of being 42 p
would then be $0\cdot42 \times \frac{1450}{1360} = 0\cdot448$ nearly, an increase of about 6½ p

The above estimate having been made for one of the most not
cases, it seems probable that efficiencies as given in Column 42, and co
sumptions as taken from Column 34, of Table XXXIII are not likely to be

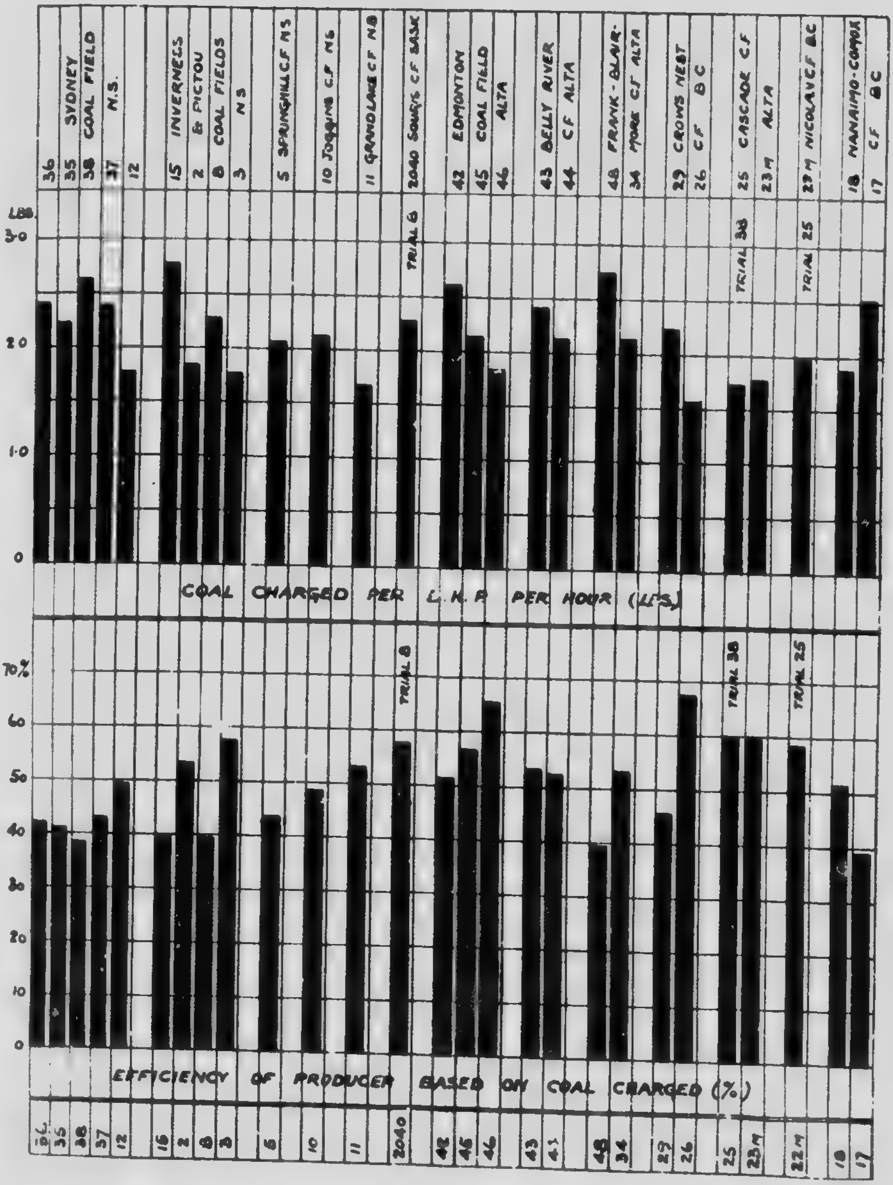

Fig. 19. Diagram showing producer efficiency and coal consumption per B. H. P. per hour

more than 7 to 10 per cent on account of the burnt down or overcharged condition of the fuel bed at the end of the test as compared with the condition at the beginning

The lower diagram of Fig. 19 shows in graphic form for purposes of comparison the producer efficiencies based on the coal charged and on the lower calorific value of the gas generated. The upper diagram enables a comparison to be made between the coal charged per B.H.P. per hour in the different cases. Where two tests have been made with the same coal, the better result of the two is given.

RELATIVE MERIT OF THE COALS

For various reasons it has not been thought advisable to assign any index number as a guide to the relative merit of the various coals tested in the producer, the chief difficulty in assigning such numbers arising from the uncertainty as to whether the best results were obtained in each case, and from the fact that one producer had to be used for all the bituminous coals, to some of which its design was better suited than to others. Further, there is at present no standard coal occupying the same well known position with regard to gas producer work as is held by Welsh coal, Pocahontas, or Georges Creek in connexion with boiler tests. Comparisons, where made, must, therefore, be more general in their nature than in the work of Part VII, and it must also be borne in mind that the economic results given would have been considerably higher if the work could have been done on a larger scale.

In the following notes the coals are taken by geographical groups, and it is believed that the information given is sufficient to enable the reader to form an opinion as to the difficulties of working a given coal in the producer as well as to its probable economic performance in producer work.

Fuller details as to the tests with each coal will be found in Vol. V, where the complete logs and observation sheets are reproduced for the whole series.

REMARKS ON COALS AS ARRANGED GEOGRAPHICALLY BY COAL FIELDS

SYDNEY COAL FIELD, CAPE BRETON COUNTY, N.S.

Four gas producer trials were made on coals from the mines of the Dominion Coal Co., and one trial on a coal from one of the Nova Scotia Steel & Coal Co.'s mines.[1]

These are all bituminous coals containing from 50 to 60 per cent of fixed carbon, 32 to 35 per cent of volatile matter, and varying amounts of ash. They gave gas somewhat low in calorific value, and the producer efficiency was rather low with the D. C. Co.'s samples on account of the amount of poking required, and the combustible wasted in the refuse. Coal No. 12 was the most satisfacto and next, coal No. 37. Results from Nos. 36, 35, and 38 are probab slightly too low, as the fuel bed was found to be rich in combustible at the e of the trial in each of these cases. The coals Nos. 12 and 37 are fairly suital for power producer work; the others involve considerable labour in a sm producer, but would probably do better on a larger scale.

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[1] NOTE.—All the tests, except where otherwise specified, were made with Producer No. 4.

TABLE XXXV

Performance with Cape Breton Coals

Coal No.	36	35	38	37	12
Description	Hub seam D.C. Co.	Harbour seam D. C. Co.	Phalen seam D. C. Co.	Emery seam D. C. Co.	No. 2 Colliery N.S.S. & C. Co.
Volatile matter . . . . %	35·0	35·1	32·5	34·2	35·4
Ash . . . . %	5·0	10·9	6·5	11·1	7·8
Moisture . . . . %	2·4	1·4	2·2	2·4	3·6
Cal. value of coal as charged . . . . B.T.U.	13520	13800	13700	12840	13180
Cal. value of gas (lower) per cub. ft. . . . . B.T.U.	106·5	107·3	110·0	100·3	98·0
Producer efficiency . . .	0·420	0·408	0·385	0·432	0·491
Coal per B.H.P. per hr. . . . . lbs	2·40	2·21	2·63	2·39	1·76
Caking of coal	tends to cake	some trouble	tends to cake	slight	no trouble
Average interval between poking	1 hour	55 mins.	1 hour	2 hours	1¼ hours
Clinker	no trouble	trouble from arching	small amount	no trouble	no trouble
Tar	94 lbs.	148 lbs.	137 lbs.	97 lbs.	83 lbs.
Uniformity in gas quality.	rather variable	variable	rather variable	rather variable	fairly uniform
Amount of steam used .	moderate	moderate	small	moderate	moderate
Combustible in refuse.	low in combustible	high in combustible	very high in combustible	moderate	moderate
Remarks	considerable attention needed, but should have done better	great deal of attention needed but should have done better	good deal of attention, not very good for producer work	not much attention, fairly suited for producer work	not hard to work, fairly suited for producer work

INVERNESS AND PICTOU COAL FIELDS, N.S.

One trial with coal from the Port Hood colliery, Richmond Railway & Coal Co., Inverness county, two from mines of the Acadia Coal Co., and one from the Intercolonial Coal Co., Pictou county, N.S.

These are bituminous coals somewhat high in ash; the Port Hood coal is rather high in volatile matter, and appears the least suitable for power-gas work. Coal No. 3 (Drummond colliery), in spite of its ash, gave the most satisfactory results. All four coals were easily worked in the producer. The economic results from coal No. 8 are probably slightly too low, as the fuel bed was rich in combustible at the close of the trial. A repeat of this test would have been made if sufficient material had been available. On the whole, these coals gave very good results.

TABLE XXXVI

Performance with Inverness and Pictou Coals

Coal No.	15	2	8	3
Description	Port Hood colliery, Richmond Ry. & Coal Co., Inverness co., N. S.	Cage Pit seam, Albion colliery, Acadia Coal Co. Stellarton, Pictou co., N. S.	Main seam, Acadia colliery A. C. Co., Westville, Pictou co., N. S.	Main seam, Drummond Colliery I. C. Co., Westville, Pictou co., N. S.
Volatile matter ..... %	35·3	30·9	27·5	24·0
Ash .... %	12·7	10·9	9·0	12·0
Moisture .... %	2·8	1·9	1·9	1·3
Cal. value of coal as charged .... B.T.U	11440	12920	13600	12780
Cal. value of gas (lower) per cub. ft. .. B.T.U.	116·1	93·6	94·9	97·7
Producer efficiency	0·398	0·533	0·393	0·578
Coal per B.H.P. per hr. lbs	2·78	1·83	2·28	1·76
Caking of coal	very little	no trouble	no trouble	no trouble
Average interval between poking	2½ hours	2¼ hours	2 hours	2¼ hours
Clinker	no trouble	no trouble	no trouble	no trouble
Tar ...	70 lbs.	7 lbs.	55 lbs.	45 lbs.
Uniformity in gas quality	fairly uniform	fairly uniform	moderate	fairly uniform
Amount of steam used .	small	considerable	small	considerable
Combustible in refuse .	rather high in combustible	low in combustible	high in combustible	moderate
Remarks	fairly suitable for producer work	easily worked, good for producer work	easily worked, but made poor gas, should have done better	very little attention, good for producer work

SPRINGHILL AND JOGGINS COAL FIELDS, N.S., AND GRAND LAKE COAL FIELD, N.B.

Three trials were made, one coal from each field being taken. These bituminous coals are of fair quality for producer use, although rather high in ash. Coal No. 11 gave the most satisfactory results, but yielded much tar. All three were readily worked in the producer and gave gas of low calorific value. With coal No. 10 the fuel bed was somewhat rich in combustible at the end of the trial, and the efficiency given is, therefore, slightly lower than the real value.

TABLE XXXVII

Performance with Springhill, Joggins, and Grand Lake Coals

Coal No.	5	10	11
Description	No. 2 colliery, Cumberland Ry. & Coal Co., Springhill, N.S.	Joggins colliery, Canada Coal & Ry. Co., Joggins, N.S.	King's mine Minto, N.B
Volatile matter. %	31·1	34·4	32·7
Ash. %	7·3	18·4	12·7
Moisture %	1·9	2·5	1·3
Cal. value of coal as charged B.T.U.	13120	11300	12720
Cal. value of gas (lower) per cub. ft. B.T.U.	93·8	98·9	98·3
Producer efficiency	0·438	0·486	0·531
Coal per B.H.P. per hour ... lbs.	2·07	2·11	1·69
Caking of coal	no trouble	no trouble	very little trouble
Average interval between poking	1 hour	1 hr. 50 min.	2 hours
Clinker	no trouble	no trouble	no trouble
Tar	34 lbs.	41 lbs.	119 lbs.
Uniformity in gas quality	rather variable	variable	fairly uniform
Amount of steam used	moderate	moderate	moderate
Combustible in refuse	moderate	moderate	moderate
Remarks	gave poor gas, but easily worked in producer	gave poor gas, but worked well in producer	gave poor gas and a good deal of tar, but very easy to work in producer

SOURIS COAL FIELD, SASK., EDMONTON AND BELLY RIVER COAL FIELDS ALTA.

Seven ordinary gas producer trials (one a repeat) and one special test were made with the lignites and lignitic coals from Saskatchewan and Alberta. The samples were mined by the Western Dominion Collieries Ltd., Taylorton, Sask.; Parkdale Coal Co., Ltd., and Standard Coal Co., Ltd., Edmonton, Alta.; Strathcona Coal Co., Ltd., Strathcona, Alta.; Canada West Coal Co., Taber, Alta.; and the Alberta Railway & Irrigation Co., Ltd., Lethbridge, Alta.

These fuels all proved excellent for use in the down-draft producer, most of them required no steam at all, and some gave so little tar that the gas washer could be dispensed with. They all have low calorific values, are moderately high in ash, and contain much intrinsic moisture. They weather rapidly and break up in the producer. Good efficiencies were obtained in each case, with gas of high calorific value and uniform in quality. Very little attention to the fire was needed, and with most of the samples the producer could have been run without the exhauster as a suction producer. The Belly River coals (Nos. 43 and 44) required slightly more attention than the others, and on the whole No. 46 (Strathcona) gave the best results.

In connexion with coal No. 2040 (Taylorton lignite) it should be noted that seven weeks (during which the fuel was kept in bags in a dry store) [illegible] between trial 8 and trial 17. The change in composition of the lignite during this time is well shown, but the ageing process did not seem to [illegible] less suitable for use in the producer.

TABLE XXXVIII

Performance with Lignites and Lignitic Coals

Coal No.	2040	2040	42	45	46	43	44
Description.	Lignite from Western Dominion Collieries Ltd., Taylorton, Sask.		Lignite from Parkdale Coal Co., Ltd., Edmonton, Alta.	Lignite from Standard Coal Co., Ltd. Edmonton, Alta.	Lignite from Strathcona Coal Co., Ltd., Strathcona, Alta.	Lignitic coal from Canada West Coal Co., Ltd., Taber, Alta.	Lignitic coal from Galt colliery, Alta. Ry. and Irrigation Co., Ltd Lethbridge, Alta.
	Trial 8	Trial 17					
Vol. matter .... %	32·8	43·3	28·7	31·2	30·9	26·6	35·2
Ash.. ... . %	7·2	11·1	11·2	7·5	11·9	16·3	9·4
Moisture. %	23·3	13·4	17·3	15·3	16·1	12·6	7·8
Cal. value of coal as charged.....B.T.U.	8300	9370	8940	9610	9010	9650	10800
Cal. value of gas (lower) per cub. ft. B.T.U.	112·7	117·4	119·5	118·6	119·0	120·0	122·4
Producer efficiency	0·578	0·488	0·514	0·566	0·657	0·534	0·522
Coal per B.H.P. per hr. lbs..	2·28	2·48	2·61	2·13	1·83	2·42	2·13
Caking..	none	none	none	none	none	none	very slight
Average interval between poking.	5 hours	6 hours	2¼ hours	5 hours	12 hours	2¼ hours	1¾ hours
Clinker.	very slight	none	none	slight	slight	slight	none
Tar..	none	gas washer not used, no tar	none	none	none	very little from scrubber	none
Uniformity in gas quality.	very uniform	very uniform	very uniform	fairly uniform	fairly uniform	very uniform	fairly uniform
Amount of steam used	very little	none	none	none	very little	small amt.	small amt.
Combustible in refuse.	(not analysed)	moderate	moderate	(not analysed)	little combustible	rather rich in combustible	little combustible
Remarks	very suitable fuel for producer, easy to work	very suitable for producer, easy to work, no trouble	easily worked very suitable for producer	easily worked very suitable for producer	very easy to work in producer	very little trouble, easy to work	good for producer work very little trouble

In view of the good results obtained with these fuels and the fact that few bags of Nos. 40, 42, 43, 44, and 46 were left, it was decided to mix them and to run the plant 10 hours a day until they were used up, banking the at night, as would be done in a commercial installation. Trial 16 was under these conditions and lasted three days (28 hours running time, 28½ hours with fire banked). Part of the refuse removed during the day runs for banking, together with 200 pounds of fresh fuel. The gas was not washed during the test, nor was the sawdust scrubber used. No steam was to the fuel. No difficulty was experienced from tar or clinker, the fire quired very little attention, and gas for starting was easily obtained standing during the night.

The leading particulars of this trial are

Special Trial No. 16 with a mixture of lignites (Nos. 40, 42, 43, 44, and 46) (28 hours running, 28½ hours banked.)

Composition of coal: -

Fixed carbon 40·8; volatile matter 31·1; ash 9·6; moisture 18·

Calorific value as charged, 8,900 B.T.U. per pound.

Gas: calorific value (lower) 122·2 B.T.U. per cub. ft. at 60° and 14·7 per sq. in.

Steam: no steam supplied.

Total coal charged during running time . .	2365 lbs.
" " used for banking. .	200 lbs.
" " " " restarting.	350 lbs
Average B.H.P. during running time.	30·3

	Running time only	Including coal used for banking and restarting
Coal charged per B.H.P. per hr.	2·79 lbs.	3·44 lbs
Efficiency of producer and gas cleaning apparatus	0·495	0·401

Remarks: fuel very suitable for use in a producer of the down-draft type, without the supply of any steam.

All the fuels tried in this group proved easy to work and gave good results. No. 46 showed the best efficiency. They appear much more suitable for use in a properly designed gas producer than in an ordinary steam boiler. The fuel bed analysis indicates that somewhat too much fuel was charged in the case of Nos. 42 and 2040 (trial 17), while in coal No. 44 the bed was poor in combustible; the apparent efficiency given is, therefore, probably too low for No. 42 and (trial 17) No. 2040, and slightly too high for coal No. 44.

FRANK-BLAIRMORE COAL FIELD, ALTA.

Two producer tests were made, on coals mined respectively by the Leitch Collieries Ltd., Passburg, Alta., and the International Coal & Coke Co., Coleman, Alta. These are bituminous coals high in ash (18 per cent); the latter seems the more suitable for gas producer work. Both yielded gas of rather low calorific value. The apparent efficiency given for No. 48 is probably slightly too low, as the fuel bed was rather rich in combustible at the end of the test. These coals do not work so easily in the producer as the coals of the last group, and No. 48 seems better as a steam coal than for producer use.

TABLE XXXIX

Performance with Frank-Blairmore Coals

Coal No.	48	34
Description	Leitch colliery, Passburg, Alta.	No. 2 seam, Denison colliery, Coleman, Alta.
Volatile matter %	29·2	24·4
Ash %	18·7	18·1
Moisture %	1·0	1·4
Calorific value of coal as charged B.T.U.	12120	11590
Calorific value of gas (lower) per cub. ft. B.T.U.	103·9	97·3
Producer efficiency	0·397	0·529
Coal per B.H.P. per hr. lbs.	2·74	2·14
Caking of coal	cakes considerably	cakes slightly
Average interval between poking	55 mins.	2½ hours
Clinker	troublesome	no trouble
Tar	26	15
Uniformity in gas quality	not very uniform	rather variable
Amount of steam used	moderate	moderate
Combustible in refuse	moderate	low
Remarks	Scrubbers and washers did not completely remove tar, which was sufficient to render engine valves sticky. Coal needed much attention in producer.	No trouble from tar; fairly suitable for producer work

CROWSNEST COAL FIELD, B.C.

Two regular gas producer tests were made on representative Crowsnest coals (Nos. 29 and 26) from the Michel and Fernie mines of the Crowsnest Pass Coal Co., Ltd. In addition, a long trial (100 running hours) was made with Nos. 27 and 30. All these are coals of high quality, and worked well in the producer. No. 26 gave the best results and a very high apparent efficiency (67·6 per cent). The fuel bed analysis, however, shows that at the end of the trial the combustible content was low, and it is, therefore, likely that the real efficiency was less than 67 per cent. Probably the efficiency shown on the long trial (with very similar coal composition) is a more correct one (59·9 per cent). All the Crowsnest coals tested seem very well suited for power gas producer work.

TABLE XL.

Performance with Crowsnest Coals

Coal No.	29	
Description	N[illegible] mine, Michel Colliery, Crowsnest Pass Coal Co., Ltd. Michel, B.C.	No. 5 mine, C[illegible] Creek, Cr[illegible] Pass Coal C[illegible] Fernie, B.C
Volatile matter %	[illegible]	[illegible]
Ash %	6·0	10·9
Moisture %	1·4	0·8
Calorific value of coal as charged, B.T.U.	13330	133[illegible]
Calorific value of gas (lower) per cub. ft. B.T.U.	102·3	95·2
Producer efficiency	0·457	0·676
Coal per B.H.P. per hour, lbs.	2·23	1·5[illegible]
Caking of coal	Very slight	a littl
Average interval between poking	2 hours	3½ hou
Clinker	no trouble	very sligh
Tar	50 lbs.	24 lbs.
Uniformity in gas quality	fair	very unifor
Amount of steam used	moderate	considerab
Combustible in refuse	rather high	moderat
Remarks	worked well in producer	very good and [illegible] to work

A sufficient quantity of two of the other Crowsnest coals (Nos. 27 and 30) was available for about 100 hours run, and instead of making ordi[illegible] tests with these coals, it was decided to use them for a special test [illegible] ordinary commercial conditions, running 10 hours per day and bank[illegible] at night and on Sundays. This test was accordingly made from April 13 to Ap[illegible] 24, 1909, and the results are given below. The coals used were very [illegible] in character to Nos. 29 and 26 and to each other. The composition [illegible] in Table XXXIII is the average of samples collected during the trial. [illegible] the coals were not mixed, and No. 30 was used after all of No. 27 had bee[illegible] burnt, it may be noted that the calorific values of these two coals (as [illegible] the boiler trials) were respectively 13680 and 13230 B.T.U. The p[illegible] results of this test are as follows

Special Test No. 42 with Crowsnest Coals, Nos. 27 and 30.

(100 hours running, 162¾ hours banked.)

Coal used:

No. 27—from No. 2 mine, Coal Creek, Fernie, B.C., and

No. 30—from No. 7 mine, Michel colliery, Michel, B.C.

The first named coal was fired on April 13, 14, 15, 16, 17, 19, and 20 (70 hours running time), and coal No. 30 on the 22nd, 23rd, and 24th (30 hours running). The fire was banked at night, and all day on the 18th (Sunday) and 21st. (A defect in the exhaust piping, discovered on st[illegible]

[illegible] engine [illegible] the [illegible] of the 21st required [illegible] that [illegible] impossible to [illegible] a full [illegible] and the fire was [illegible] bank [illegible]. The two coals were so alike [illegible] and [illegible] not [illegible] treatment in the producer [illegible] has not been [illegible] to attempt to separate their economic result.

Composition of coal, (average of the two [illegible]

Fixed carbon 64·64, volatile matter 24·82, ash 9·57, moisture 0·[illegible],

Calorific value as charged 13586 B.T.U. per lb.

Gas: Calorific value (lower), 89·9 B.T.U. per cub. ft. at 60° and 14·[illegible] per sq. in.

Steam: 2·6 lbs. of steam per lb. of coal charged during running time.

	No. 27	No. 30	Total
Total coal charged during running time	2875	1375	4250 lbs.
Total coal used for starting, banking, and restarting fire	1225	275	1500
			5750
Average B.H.P. during running time			27·7
Average coal per hour while running	44·4		
Average coal per hour while banked	9·13		
Gas per hour (60° and 14·7 lbs. per sq. in.) cub. ft.			3840

	Running time only	Whole trial including coal used for banking and restarting fire
Coal charged per B.H.P. per hour...	1·53	2·07
Efficiency of producer and gas cleaning apparatus	0·599	0·442

Remarks: So little tar that gas washer was shut down as being unnecessary after running 6 days. The gas was passed through the sawdust scrubber for the rest of the run. Some of the refuse contained enough combustible to be used for banking at night. Calorific value of gas rather low, but quality uniform. Both coals were easily worked and gave no trouble from clinker. Condition of fuel bed at end of test (as judged from analysis) was normal. Fire was poked at intervals of about 2½ hours. The engine valves were quite free at end of test.

CASCADE COAL FIELD, ALTA.

Three regular trials and one special test were made on two samples (Nos. 25 and 23 M), mined respectively by H. W. McNeil Co., Ltd., Canmore, and by the Bankhead Mines Ltd., Bankhead, Alta. These are anthracitic coals containing 10 to 13 per cent of ash and 11 to 16 per cent of volat matter. 23 M is a more typical anthracite than the other and can be us successfully in a regular suction producer.

Both coals worked well in Producer No. 4 and gave no trouble from t or clinker. The first trial (No. 37) with No. 25 was somewhat unsatisfacto at first, on account of irregularity in the quality of the gas, but on using m steam a great improvement was found. The second trial (No. 38) was m satisfactory as to gas quality, but the fuel bed was rather poor in combusti at the end of the test, so that the efficiency given is probably somewhat high. That given for trial 37 (in Table XXXIII) is probably too low.

TABLE XLI

Performance with Cascade Coals

Coal No.	25 (Trial 38)	23 M (Trial 11
Description	No. 4 mine, H. W. McNeil Co., Ltd. Canmore, Alta	Mixed Pea and wheat, Bankh Mines, Ltd., B head A
Volatile matter %	16·7	11·4
Ash %	12·3	[illegible]
Moisture %	0·7	1·0
Calorific value of coal as charged B.T.U.	13120	12950
Calorific value of gas (lower) per cub. ft. B.T.U.	87·2	102·4
Producer efficiency	0·600	0·598
Coal per B.H.P. per hr., lbs.	4·72	1·78
Caking of coal	none	none
Average interval between times of poking	3¼ hours	8 hours
Clinker	very little, gave no trouble	no troub
Tar	20 lbs.	6 lbs. from gas washer
Uniformity in gas quality	fair	very uni
Amount of steam used	large	large
Combustible in refuse	low	low
Remarks.	worked well, but gave gas of very poor calorific value, no trouble, good producer coal	fire quite fre worked we trouble.

The remainder of coal No. 23 M after trial 11 was unfortunate in amount but was used in a test, No. 13, with the suction producer The run was unavoidably too short to measure the coal consumptio any accuracy, but gas of good calorific value was obtained (consi higher than with the larger producer No. 4), and the engine carri B.H.P. The gas was not metered, as the producer was used on dir tion. No trouble was experienced with clinker, and this coal can b successfully in a regular suction producer if it is not burnt at too rate per square foot of fuel bed. A small amount of tar began to ap the engine towards the end of the six hours.

8) COALS FROM THE NICOLA VALLEY AND THE NANAIMO COAL FIELDS, B.C.

Four regular tests (one a repeat) were made on coals Nos. 22 M, 18, and 17 from the mines of the Nicola Valley Coal and Coke Co., Ltd., Coutlee, B.C., and the Western Fuel Co., Ltd., Nanaimo, Vancouver island, B.C.

These are bituminous coals, high in volatile matter (35 to 40 per cent) and carrying a considerable amount of ash (12 to 16 per cent). Two appeared fairly suitable for producer work, the third (No. 17) gave some trouble.

The first trial with No. 22 M (trial 18) (see Table XXXIII) showed a low efficiency, the fire having been disturbed and worked too much and a large amount of refuse high in combustible value having been withdrawn. The repeat trial (No. 25) gave satisfactory results and the fuel bed at the close appeared normal. The refuse in trial 19 with No. 17 coal was relatively high in combustible but heavy poking seemed unavoidable with this coal.

TABLE XLII

Performance with Nicola Valley and Nanaimo Coals

Coal No.	22 M (Trial 25)	18	17
Description	Mixture of coal from Jewel seam, No. 1 mine, and a small amount from Rat Hole seam, No. 2 mine, Middlesboro colliery Nicola Valley Coal & Coke Co Ltd., Coutlee B.C.	Upper seam, No. 1 mine, Western Fuel Co., Ltd., Nanaimo, Vancouver island, B.C.	Lower seam, No 1 mine, Western Fuel Co. Ltd Nanaimo, Vancouver island, B.C.
Volatile matter %	36·9	40·3	39·7
Ash %	12·0	13·7	16·8
Moisture %	4·2	1·5	2·0
Calorific value of coal as charged, B.T.U.	11220	12640	12220
Calorific value of gas (lower) per cub. ft. B.T.U.	99·3	121·5	130·4
Producer efficiency	0·582	0·515	0·390
Coal per B.H.P. per hour, lbs.	1·98	1·88	2·52
Caking of coal	practically none	slight	trouble
Average interval between times of poking	4 hours	53 mins.	1¼ hours
Clinker	no trouble	no difficulty	very little trouble
Tar	30 lbs.	48 lbs.	17 lbs. very troublesome
Uniformity in gas quality	fair	fair	medium
Amount of steam used	moderate	moderate	moderate
Combustible in refuse	low	moderate	high
Remarks	worked easily, no trouble from tar or clinker.	needed attention but fire was not hard to work. Trouble with tar in engine valves	required much attention. Trouble from tar, which gas washer did not remove properly

HEAT EXPENDITURE WITH VARIOUS COALS

In Table XLIII the fuels tested have been arranged in order of the value of the amount of coal charged per B.H.P. per hour. This table the figures of Column 13, Table XXXI, but in a different order, and w give the proportional cost for fuel, assuming that all the coals were s the same price per thousand B.T.U. This order of arrangement is not fair to some coals, and gives others some slight undue advantage, but a a general idea of the relative performance of the various groups.

TABLE XLIII

Heat Value of Coal Charged per B.H.P. per Hour

Coals arranged in order of apparent economy

Coal No.	Trial No.	Description of Coal	[illegible]
46	11	Lignite, Strathcona Coal Co., Edmonton, Alta	[illegible]
20 40	8	Lignite, Western Dominion Collieries, Ltd., Taylorton, Sask	[illegible]
26	10	Coal, Crowsnest Pass Coal Co., Fernie, B.C. . .	[illegible]
45	10	Lignite, Standard Coal Co., Edmonton, Alta.	[illegible]
27 and 30	42	Coal, Crowsnest Pass Coal Co., Fernie and Michel, B.C	[illegible]
11	29	Coal, King's mine, Minto, N.B. .	[illegible]
22 M	25	Coal, Nicola Valley Coal Co., Coutlee, B.C.	[illegible]
3	23	Coal, Intercolonial Coal Co., Westville, N.S.	[illegible]
25	38	Coal, H. W. McNeil Co., Ltd., Canmore, Alta. .	[illegible]
23 M	41	Coal, Bankhead Mines Ltd., Bankhead, Alta..	[illegible]
44	13	Lignitic coal, Alberta Ry. & I. Co., Ltd., Lethbridge, Alta.	[illegible]
12	30	Coal, Nova Scotia S. & C. Co., Sydney Mines, N.S	[illegible]
42	15	Lignite, Parkdale Coal Co., Ltd., Edmonton, Alta.	[illegible]
43	12	Lignite, Canadian West Coal Co., Ltd., Taber, Alta	[illegible]
2	24	Coal, Acadia Coal Co., Ltd., Stellarton, N.S..	[illegible]
18	20	Coal, Western Fuel Co., Nanaimo, B.C.	[illegible]
10	27	Coal, Canada Coal & Ry. Co., Ltd., Joggins, N.S..	[illegible]
34	36	Coal, International Coal & Coke Co., Coleman, Alta.	[illegible]
5	22	Coal, Cumberland Ry. & Coal Co., Springhill, N.S .	[illegible]
29	35	Coal, Crowsnest Pass Coal Co., Fernie, B.C. . .	[illegible]
35	31	Coal, Dominion Coal Co., Ltd., Glace Bay, N.S. . .	[illegible]
37	33	Coal, Dominion Coal Co., Ltd., Glace Bay, N.S. .	[illegible]
17	19	Coal, Western Fuel Co., Nanaimo, B.C.	[illegible]
8	26	Coal, Acadia Coal Co., Ltd., Westville, N.S .	[illegible]
15	21	Coal, Richmond Ry. & Coal Co., Port Hood, N.S.	[illegible]
36	32	Coal, Dominion Coal Co., Ltd., Glace Bay, N.S.	[illegible]
48	14	Coal, Leitch Collieries, Ltd., Passburg, Alta. . .	[illegible]
38	34	Coal, Dominion Coal Co., Ltd., Glace Bay, N.S. . .	[illegible]

Perhaps the most striking result of the series of tests is the performance of the lignites, which is well seen in this table, all th taking good places. The Crowsnest coals, and Alberta anthracite seen to have given good results. The lower places in the table (generally speaking) by coals whose caking qualities render th to handle in a gas producer of small size.

THE

COALS OF CANADA:

AN ECONOMIC INVESTIGATION

VOL. II

PART IX

WORK OF THE CHEMICAL LABORATORY

BY

EDGAR STANSFIELD

PART IX

WORK OF THE CHEMICAL LABORATORY

EDGAR STANSFIELD

INTRODUCTION

The Chemical Laboratory was required to make full analyses of all coals sampled and of all products obtained in tests carried out in the different sections of the investigation. The work that had to be done was thus very considerable, especially as all methods and apparatus had to be tested and standardized, and in a number of cases new methods had to be devised and new or modified apparatus designed and built. All materials, whether raw, intermediate, or final products, had to be analysed, and although no attempt was made to keep count of the number of analyses made, a rough idea of the amount of work done can be got from the fact that a complete test of a single coal involved over four hundred separate determinations, and that over one hundred distinct consignments of coal were more or less fully tested. These facts, together with the following enumeration of the different analyses, determinations, and investigations carried out, will give some impression of the magnitude of the work involved.

Materials Analysed.—Coal samples: main, mine, weathering, boiler trial, gas producer trial, coking test, final washed coal, and separate products of washery, specific gravity tests, screen analyses, etc. Coke samples: from coking tests and special samples. Gas samples: from boiler trials, gas producer trials, and coking tests. Ash samples: from boiler trials, gas producer trials, and laboratory combustion of raw and washed coal.

Chemical Determinations Made.—Carbon, hydrogen, oxygen, sulphur, nitrogen, moisture, ash, volatile matter, fixed carbon, and combustible matter, in solids; and carbon dioxide, ethylene, oxygen, carbon monoxide, methane, hydrogen, nitrogen, sulphur dioxide, and hydrogen sulphide in gases.

Physical Determinations Made.—Fusion temperatures of ashes; specific gravity, porosity, and strength of cokes; calorific values of solid and gaseous fuels; vapour pressures; calibration of gas meters, ammeters, voltmeters, [illegible] meters, calorimeters, etc.

Special Investigations have been made on: the determination of sulphur in coal, determination of volatile matter in coal and also in coke, solubility [illegible] in water, determination of physical values of coke, weathering of coal, etc.

The analytical work was mainly carried on in the private chemical laboratory of the Professor of Mining Engineering at McGill University; this room was conveniently situated and well equipped, and proved satisfactory in most respects, but it only afforded space for two chemists at work at once without inconvenience, and therefore, during the summer months, when the sampl came in most rapidly, a second and larger room adjoining it was also used a the staff increased. A number of gas analyses and ultimate analyses w made in the special rooms set apart for these operations in the Department Chemistry; other gas analyses were made in rooms conveniently near to experimental boilers and gas producers; crushing tests on coke were m in the testing laboratory of the Department of Civil Engineering; fusib tests of ashes, and some other tests, were made in the furnace room of Department of Metallurgy; and certain physical instruments were calibrat in the laboratories of the Department of Physics. Thanks are due to heads of the above departments of McGill University for their courte allowing the use of their rooms and equipment.

The actual work of sampling, mechanical purification, and of b trials, was mainly done in the summer months when the several laborato were not required for educational purposes, but the private chemical lab tory, above mentioned, was placed exclusively at the service of the coal t staff, and in it work was carried on continuously from the spring of 1907 the spring of 1910. During the summer months of each year, the prepar of samples, and work on certain urgently required analyses kept the staff occupied, and at the end of each summer there were considerable arre work which had to be made up later. It would have been more satisfacto to have made a complete analysis of each coal sample when received, but th would have necessitated a far larger staff and equipment than circumsta permitted.

The regular methods of analysis adopted in the routine tests are des below; the preliminary investigations carried out before deciding on methods, together with other special investigations, will be found desc in Appendix V. Vol. VI. A summary of results of analyses regular coal samples is given in Tables LIV to LXXI, following page 18 other analyses will be found in Parts V. and VI. Volume I. Parts VII VIII. Volume II. and in the several appendices to the subsequent volu

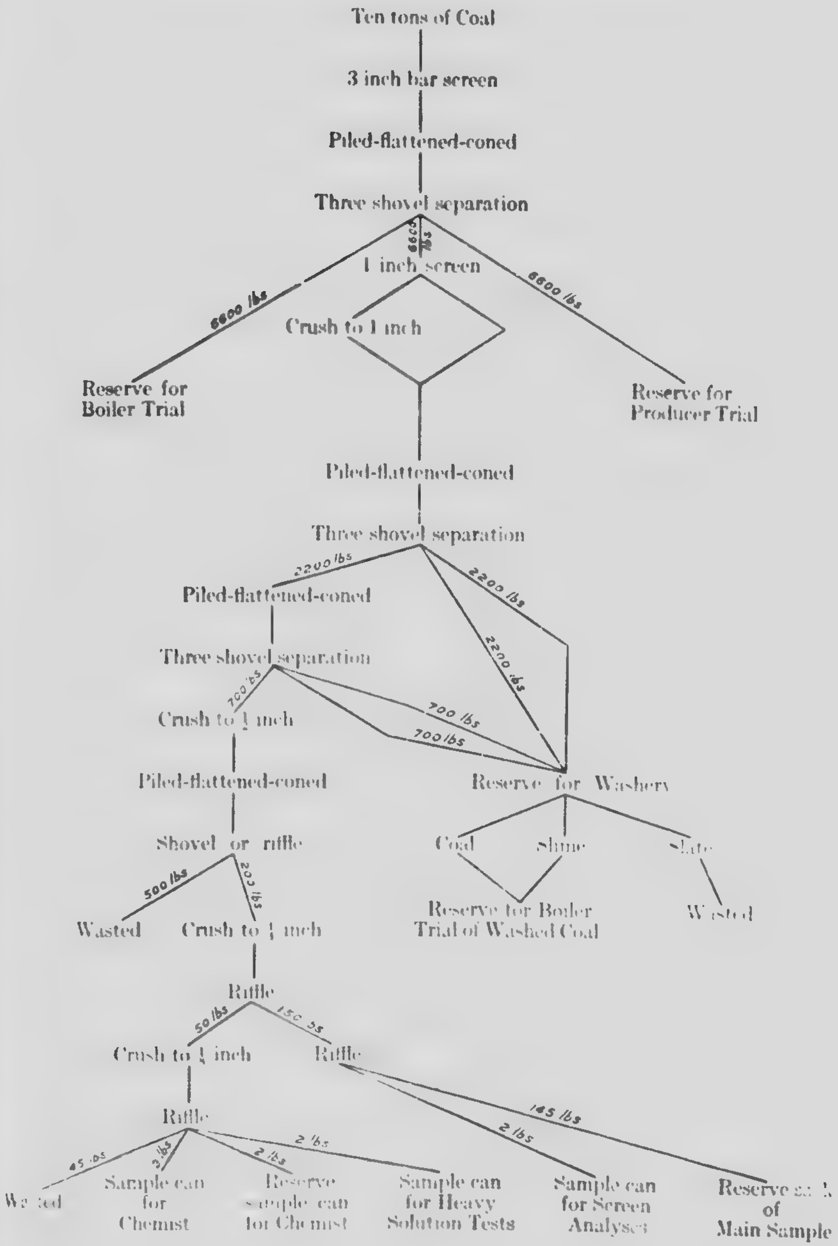
The following trained chemists have assisted in the work: Mr. J. H. H Nicolls, Mr. R. T. Mohan, Mr. P. H. Elliott, Mr. E. J. Conway, Mr. W. B Campbell, Mr. W. B. Meldrum, Mr. R. S. Boehner, Mr. H. Hartley, and M H. G. Morrison.

COLLECTION AND TREATMENT OF SAMPLES

COAL SAMPLES.

Regular Sample.—Each main consignment of coal was carefully s on arrival at the plant. In the case of the first few samples, which wer with in 1907, the method of coning and quartering was used, but sequently the three shovel method was adopted and carried out as in in the accompanying flow sheet. The weights shown are appro only, and are estimated for a ten ton sample.

FLOW SHEET SHOWING ORDINARY TREATMENT OF MAIN SAMPLE



The *Regular Chemist's Sample* was placed in a sample can, carefully mar and sent immediately to the laboratory, where the whole lot was gro for three or four hours in a small iron ball mill of 8″ diameter b deep, inside measurements, see Plates LII and LIII. The ordinary ch was: 4 hardened steel balls of 1¾″ diameter, 16 of 1½″, and 4 of 1″, and 2 po d of crushed coal; with smaller samples fewer balls were used. In all the mill was operated at about 100 revolutions per minute. The thus ground to an almost impalpable powder, was passed through a 30 sieve to ensure there being no unground nodules of pyrites; in the ve cases in which these were found they were ground up in an agate mortar a carefully remixed with the sample.

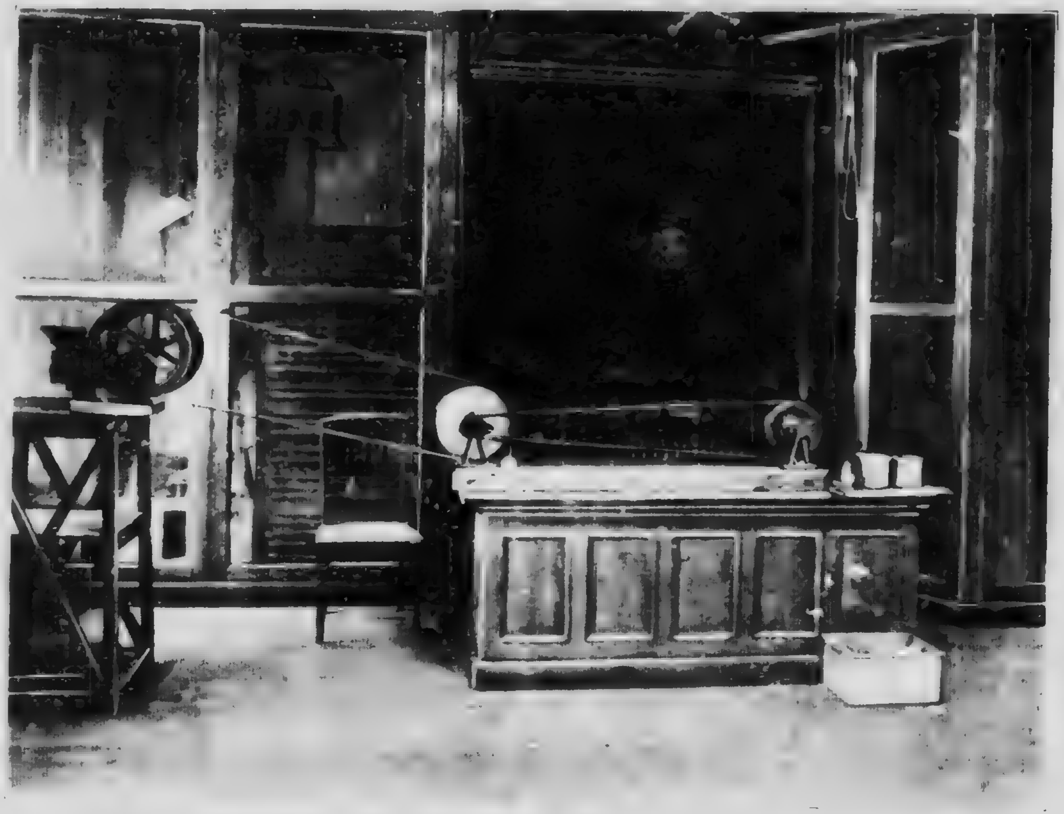
This ground sample was cut down by means of a riffle; about 200 g were burned to furnish a sample of ash, from 50 to 100 grams were spread o on a tray 12″ by 10″ and dried in an oven at 105° C. for an hour, and the remainder was returned to the can and stored. The dried coal was taken the oven at the end of the hour, and, whilst still hot, about fourteen sp tubes were filled with it; the coal being taken with a small spatula from sev parts of the tray for each tube. The tubes were at once corked and p in a bottle which was also corked, the tubes and bottle were carefully labelle "Dry coal No. . . . ," the label on the bottle being also dated. Tw of the above specimen tubes held about two grams each, the others about o gram; the coal from one of the larger tubes was briquetted for the calori the other tubes of coal were used for the regular analyses, a fresh tube be used for each determination. Beside the above, three or four 1 gra sample tubes were filled with coal from the ball mill directly it was open these were stored in another bottle and labelled "Raw coal No. . .

The Mine Sample of coal usually arrived at the laboratory by express a sample can, considerably earlier than the main consignment which ca by freight, in sacks; after opening the can, the coal was rapidly pass through a jaw crusher set at about ¼″, and then spread out on a couple of 12″ by 10″, weighed, and dried in the air drying box as described later air dried coal was all ground in the ball mill and sample tubes were fill air dry coal directly after opening the ball mill, and with dry coal tray of coal, obtained by riffling down the air dried coal from the m drying in an oven for one hour at 105 C

Samples of Coal for Weathering Tests.—The way in which th treated will be described in Appendix V, Vol. VI

Washed Coal Sample.—A sample can of coal was obtained from product of each washing either by coning and quartering or by shovel method, and then ground in the ball mill, etc., etc., exactly a main sample, except that in cases where a coal was perceptibly dam given a preliminary drying on a tray with gentle heat before grin water driven off in this way was determined and its weight added found in the ground sample to give the total water in the original sa

Plate LII.



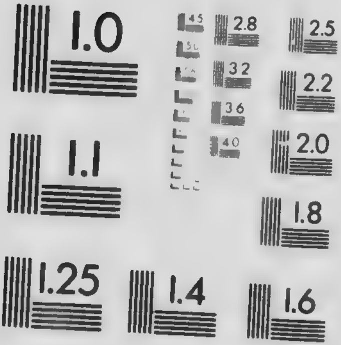
Small ball mills for grinding samples—Department of Mining and Ore Dressing, McGill University.

Plate LIII

Small ball mill opened for cleaning. Department of Mining and Ore Dressing, McGill University.

MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No 2



APPLIED IMAGE Inc

The following example will make clear the calculations necessary:

947 grams of coal lost 87 grams of water in the preliminary drying, that is 9·19 per cent. 0·9815 grams of the partially dried coal after grinding lost 0·0274 grams of water when heated for one hour at 105° C., that is 2·79 per cent.

2·79 per cent of the partially dried coal is equivalent to $2·79 \times \frac{100 - 9·19}{100}$ per cent of the original sample, that is to 2·53 per cent. Therefore the total water in the original sample is 9·19 + 2·53 = 11·72 per cent.

Samples of the different products of the washery, and portions obtained from heavy solution tests and screen analyses, etc., were ground on a bucking board or in an agate mortar instead of in the ball mill, and the ground samples were stored in 2 ounce bottles instead of in small specimen tubes.

Samples of Coal from Boiler and Producer Trials.—These samples were taken during the course of a trial; one shovel full of coal being taken from each lot weighed out in the case of a boiler trial, or each time of charging in the case of a producer trial, and put in a large galvanized iron receptacle with a close fitting lid. At the end of the trial the whole sample collected was sent to the sampling room where it was crushed to ½″ and riffled down to fill a sample can; this operation could be completed within five minutes so that any moisture change would be inappreciable. This can sample was sent to the laboratory where it was ground in the ball mill, and some sample tubes filled with the fine coal direct from the mill. In some cases of boiler trials of washed coal a preliminary drying was necessary before grinding; the moisture driven off being determined and added to that subsequently found.

These boiler trial samples were "grab samples" primarily intended for determination of the moisture in the coal as fired, although ash and sometimes volatile matter and fixed carbon were also determined. The regular samples of the original and of the washed coal were so much more carefully taken and analysed that it was considered that the results obtained, corrected for the moisture found in the coal samples as taken above, would be more uniformly close to the true analysis of the coal as fired than results obtained from the product of any method of grab sampling possible during the course of a trial.

The sample cans referred to above were made of stout tinned iron and had pelly lever lids, i.e., tight fitting lids of the type commonly used for paint cans; they were 5″ diameter and 5″ high and held about a kilogram of crushed coal. Each can was enclosed in a slightly larger one with a slip on cover, the purpose of the outer can being to protect the inner one from physical damage. It was found that even these double cans did not entirely prevent moisture changes in the contained coal, but the loss of moisture between the mine and the laboratory could only be small. The lids of the cans containing the later mine samples, amongst which were the lignites, were sealed with paraffin wax. The can samples were marked by having their number stamped on the bottom and lid of both inside and outside cans.

All bottles and specimen tubes were closed with corks which had been impregnated with paraffin wax.

ASH SAMPLES

Regular Ash Samples were obtained by burning about 200 grams of the finely ground coal sample on roasting dishes in a muffle furnace.

Samples of Ash from Boiler and Producer Trials were obtained by taking all the ash and clinker removed during the trial and successively crushing and quartering or riffling until a small sample was obtained, which was finally ground on a bucking board to pass an 80 mesh screen, and sent to the chemist in a bottle.

COKE SAMPLES

Representative pieces of coke were chosen, as described in Part VI, Vol. I; these were crushed and riffled down to a small size and then ground on a bucking board to pass an 80 mesh screen, the product, which would weigh about 100 grams, was put in a bottle, labelled, and sent to the chemical laboratory.

It was found undesirable to grind coke in an iron ball mill as the abrasion of both the mill and the steel balls was quite noticeable.

GAS SAMPLES

Flue Gas Samples were taken from the back of the boiler in front of the opening into the flue leading to the chimney, full details being given in Part VII. For the first thirty boiler trials the flue gases were drawn off through an iron tube; this was afterwards replaced by a steel tube, enamelled both inside and out, which was used in all subsequent trials. As certain constituents of these gases react together when passed over the surface of strongly heated iron, the change to the enamelled tube was made to prevent any possibility of the gas being changed in composition when passing through the sampler tube, which is exposed to the heat of the boiler flue.

During the summer of 1907, the flue gas analyses were made in an Orsat-Muncke apparatus, and the gas was aspirated from the flue through the sampler tube and the connecting tubes and through a three-way cock in the apparatus itself. When all air had been displaced by flue gas the three-way cock was turned, thus admitting the sample directly into the measuring vessel of the apparatus. In all later boiler tests the gases were drawn through the sampler tube and through connecting tubes and a T tube to a water jet exhaust. A couple of 500 c.c. aspirator bottles, shown in Plate LVII, containing a mixture of equal parts of glycerine and water, and connected together through the side tube at the bottom of each bottle by rubber tubing, were used to collect the sample. One of the bottles was connected to the T tube mentioned above, by rubber tubing, with a spring clip on it; by raising the second bottle and opening the spring clip, the first bottle and connecting tubes were filled with glycerine and water, up to the junction of the T tube past which the stream of flue gas was flowing. A sample of gas was then drawn into the bottle by lowering the second one, the spring clip closed, the tube disconnected from the T tube and the sample taken to the laboratory. The gas was kept under pressure, by keeping the second bottle uppermost, until it was transferred to the Randall and Barnhart apparatus for analysis, all possibility of leaks of air into the gas being thus avoided.

A mixture of glycerine and water has only slight solvent action on gases of the character tested and is probably the best substitute for mercury when collecting gas samples.

Producer Gas Samples were taken from a stop-cock tapped into the gas main on the pressure side of the blower. Aspirator sampling bottles like those described above were used, and the sample taken to the gas laboratory and transferred to the gas analysis apparatus; but at night, when it was not possible to proceed at once with the analyses, the samples were collected over water in 250 c.c. bottles, the water being driven as completely as possible out of the bottles which were then corked, labelled, and stored neck downwards in a tray of water. When the gas was required for analysis the bottles were uncorked under water and the gas withdrawn into an aspirator sampling bottle by means of a suitably bent glass leading tube.

Coke Oven Gas Samples were taken from the top of coke ovens at the Nova Scotia Steel and Coal Co., and also from the flues between the ovens and the chimney. An iron pipe of about $\frac{3}{8}$″ bore and 20 feet long was passed through the observation hole in the top of the door of an oven, in order to withdraw the gases from the top of the charge; a shorter pipe was used to take samples from the underground flues, special holes being drilled through the brickwork of the tunnel to admit the pipe. Gas was aspirated through the pipe and connecting tubes, and through a glass sample tube of about 20 c.c. capacity, by means of a rubber hand pump or by a couple of large bottles used as an aspirator, at least 5 litres of gas being drawn through. The gas sample tubes were shaped like a cylindrical pipette for liquids, but had a constriction in the tube on either side of the bulb; when they were filled with the required gas they were temporarily closed by spring clips on the connecting rubber tubes, taken to the laboratory close by and at once sealed off at the constrictions by means of a gas flame. When the samples were required for analysis the ends of the tubes were broken off under mercury in a deep trough and the gas transferred to hard glass test tubes in which it could be stored over mercury until transferred to the Bone and Wheeler gas analysis apparatus; one tube of gas was sufficient for at least two complete analyses in this apparatus.

NUMBERING OF SAMPLES

Owing to the large number of samples, of one sort and another, which were derived from the coal taken from each particular colliery or seam sampled, it was necessary to devise a system of numbering which would at once indicate the relation of each sample to its fellow and still preserve its individuality. The scheme adopted, which was found to work very we[illegible] [illegible] be best explained by the following illustrations.

When a regular sample or main sample was taken at the collie[illegible] was put into sacks marked with leather tags having a serial number [illegible] wh[illegible] ran from 1 up stamped on them; this number was incorporated in [illegible] laboratory number of all samples from this mine.

An example will make this clear:

Suppose the main sample of coal was	
The mine sample would be numbered	1[illegible]
The final sample of washed coal. . .	2[illegible]
The coal sample from boiler trial of the original coal.	[illegible]
The ash sample " " " " " " "	[illegible]
The coal sample from the boiler trial of the washed coal	[illegible]
The ash sample " " " " " " " " "	6[illegible]
The coal sample from producer trial of the coal. . . .	7[illegible]
The ash sample " " " " " " .	8[illegible]
If the remainder of the original coal were resampled at a later date the resulting laboratory sample would be. . . .	10[illegible]
A boiler trial sample after this resampling would be	13[illegible]
A second consignment of coal from the same mine and seam would be.	20[illegible]
And a third consignment	30[illegible]

If the original coal were, for example, 3, then the mine sample would be 103 and so on.

In some cases a sample of coal was sent from the mine in two parts, these were sampled separately then mixed and re-sampled; all three samples were analysed, but boiler trials, etc., were carried out on the mixed coal [illegible] These two parts of the sample were originally distinguished by the label[illegible] the one having been split with a knife. Suppose the number on the tags to be 22, then:

Coal from the sacks with the whole tags would be.	22
" " " " " " split tags	22 SP
And the mixed coal.	22 M
A coal sample from the boiler trial of the mixed coal.	322 M

and so on.

Samples of coal from heavy solution tests, etc., bore the number of the original coal, followed by distinctive letters and numbers.

Extra samples of coal which had not been included in the original scheme were numbered Ex. 1, Ex. 2, etc.

A sample of coke made from coal 33 if it were made in:

An Otto-Hoffman oven at Sydney would be	C1 33
A beehive oven at Bridgeport	C2 33
A Bernard oven at Sydney Mines.	C3 33
A Bernard oven at Lille.	C4 33
A beehive oven at Coleman	C5 33

Special samples of coke were marked C1, C2, etc.

Samples were marked dry, air dry, or raw according to the drying treatment they had, or had not received.

RECORDS AND CALCULATIONS

All records were kept, and weighings, etc., entered as made, by each chemist in his laboratory book; the calculations necessary for a determination were made from the weighings and entered in the same book. From time to time this work was transferred to the regular record books, a separate book being kept for each class of work; one, for example, was used for keeping a record of samples received, another for moisture determinations, and so on. This writing was made with a hard pencil, carbon duplicates being made which were filed away in the University vaults. Only the original, essential figures were copied from the laboratory books when transferring analyses, all subtractions and other calculations were made afresh from the original data as copied and the results were then compared with those previously obtained; this method checking both the copying of the data and the accuracy of the calculations. When the first calculations were made with four figure logarithms, a 10" slide rule was used, if possible, for checking, and vice versa; but the fourth significant figure of the result, if required, was always entered as found by the logarithms. The results obtained were also entered on record sheets, one of which was kept for each coal; it will be seen from the sample sheet appended that the results of the actual determinations are entered in the first three columns, the final analysis as reported being given in the last column. Most determinations were carried out, and calculations made, to give one more significant figure than in the result finally reported.

TABLE XLIV

Reports of Analysis of Coal Coal Testing Laboratory.

McGILL UNIVERSITY, DEPARTMENT OF MINING ENGINEERING.

		1	2	3	Final
1	SAMPLE 27. *No. 2 mine, Coal Creek colliery, Crow's Nest Pass Coal Co., Fernie, B.C. "Commercial screened coal." Dumped [illegible] 2" shaking screen and passed over [illegible] picking belt running 80 feet per minute.*				
2	MOISTURE —In Mine Sample —loss on air drying. .	0·90		..	0·9 %
	further loss at 105 C. (221°F.) *(ash in sample — 5·13%)* . . .	1·34			1·3 %
	total moisture.	2·23		.	2·2 %
3	In Coal as charged into Boilers —Boiler Test No. *G. C. T. 37 (ash in sample [illegible]%)* . . .	0·97			1·0 %
4	In Coal as charged into Producers Producer Test No.	..	.	.	%
	PROXIMATE ANALYSIS OF DRY COAL				
	Fixed carbon (by difference).	. . .			64·7 %

TABLE XLIV—Continued.

Report of Analysis of Coal Coal Testing Laboratory.

McGill University, Department of Mining Engineering.

		1	2	3		
8	Volatile matter on dry coal.	26·12			26·3	
9	on sample as received corrected for moisture [illegible]	25·86				
10	Ash coal burnt in muffle. .	8·96			9·0	
11	coal burnt over burner					
12	coal burnt in oxygen. .	9·29	9·29			
	Ultimate Analysis of Dry Coal					
13	Carbon.	79·20	79·31		[illegible]	
14	Hydrogen	4·41	4·41		[illegible]	
15	Sulphur by Eschka's method. .	0·47			0·5	
16	by.					
17	in rinsings from calorimeter. .	0·34	0·37	. . .		
18	Nitrogen.	1·15	1·17		1·2	
19	Oxygen (by difference). .			. . . . .	5·6	
	Calorific Power of Dry Coal			. . . .		cal. p
20	by Mahler Bomb, calorimeter. .			. . . . .		B.T.U
21	" " "	7691	7667	. . . .	7,680	cal. p
22	by F. Kohler calorimeter				13,820	B.T.U
23	" " "					
24	by calculation, reckoned to water at atmospheric temperature. . . .				7,690	cal. p
25	by calculation, reckoned to water at atmospheric temperature. .			. . . . .		B.T.U
26	Coking Properties of Coal *Large cake of friable coke* . .					
27	Specific Gravity of Coal apparent					
28	real. .					
29	Combustible Matter in Dry Ash from Boiler Test No. *G.C.T. 37*. . . .	25·5	. .	. . . .	25·5	
30	from Producer Test No. . . .		. . .	. . . .		
31	Melting Point of Ash degrees Centigrade.			. . . .		°C
32	degrees Fahrenheit					°F
33	Other Analyses *Ratio FC/VM*		. . . .	. . . .	2·46	
	Ratio C/H.		. . .	. . . .	18·0	

Remarks

Chemist

AIR DRYING COAL

The quantity of water included when coal is bought or sold is usual considerable item. Different consignments of coal from the same mine a seam are liable to have moisture contents which differ greatly according t climatic conditions. At the same time, however, there does seem to be for a particular coal, a definite figure towards which the percentage of moist tends to approximate when the coal is left exposed to the air but protec from rain: this figure can be described as the percentage of water i coal. As this percentage is only approximately constant—it increases i dam weather and decreases in dry—it was thought advisable to adopt as a standar method of air drying, one which would be independent of variations in the atmospheric conditions. The method decided upon was that of exposing the crushed coal to air moistened by means of calcium chloride solution of specific gravity 1·30, until it ceased to lose weight, and the convention was adopted that air dried coal is coal that has been treated in this manner.

Calcium chloride solution of the above strength has a vapour pressure which is approximately 0·58 times that of water, so that air standing in contact with the solution has a humidity of 58 per cent, this not being affected by small changes of temperature. Fifty-eight per cent humidity was chosen as being an average atmospheric condition.

This process of air drying was only carried out on the mine samples sent direct in the double sample cans as described above. The cans were opened and the coal rapidly crushed to ¼″ size in a jaw crusher, spread out on two 12″ × 10″ trays and weighed, the trays were then placed in a special box made reasonably air-tight, in which small laths took the place of shelves to allow free air circulation, and in which were also placed a number of trays containing lumps of pumice stone standing in the calcium chloride solution (1·30 specific gravity determined at 15°C.) See Plate LIV. The trays of coal were weighed from time to time: it was generally found that they lost in weight for about a week or ten days and then began to gain slightly, this gain was probably due to oxidation; the maximum loss was taken as the water lost on air drying. The air dried coal was ground in the ball mill and the moisture left in the ground sample determined as usual. Some lignites were found not to give a minimum weight as above even after six weeks, so the air drying was stopped when the rate of loss became very slow; but results obtained on high moisture coals are not likely to be very consistent.

The coal as charged into the boilers or producers (excluding washed coals and lignites) would ordinarily be described as dry coal. An examination of 35 coals showed the average water in the coal as charged into the boiler to be 2·14 per cent and in the corresponding mine samples air dried, to be 1·95 p[illegible]ty of these coals had an average of 1·72 per cent water as charged [illegible]ucers and 1·60 per cent in the corresponding air dried mine s[illegible] agreement is only fairly close, but at the same time the figures g[illegible]. that the water left in coal air dried as above, is approximately the same as that found in what may be described as commercial dry coal. The average moisture in the above 35 mine samples as received, and before air drying, was 2·94 per cent, the average loss in air drying was, therefore, 1·0 per cent.

ANALYTICAL METHODS AND DERIVED RESULTS

GENERAL REMARKS

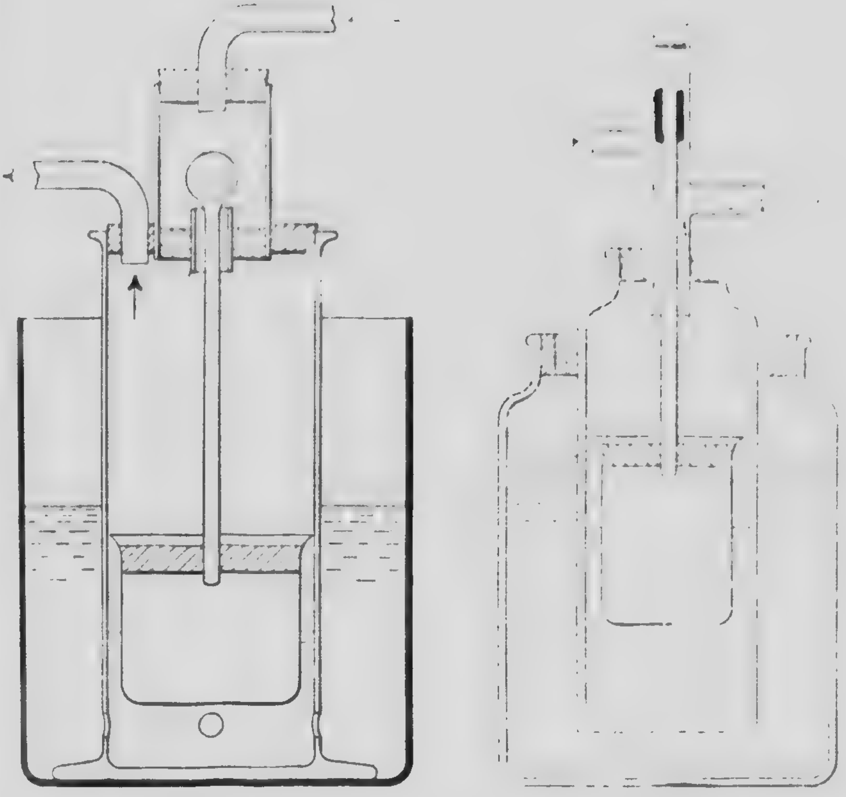
The equipment of the laboratory included the following apparatus not elsewhere described in this report: a Sartorius balance and weights; a power driven agate mortar grinder; a specially designed hot air oven; a Mason hygrometer; a gas heated hot plate; an electrically heated plate; and the usual apparatus and fittings of a chemical laborat None of these requires description except the oven which was about 24 12" × 12" inside dimensions with six shelves, heated by gas from the and arranged so that it was impossible for the burnt gases to enter the and so that the air which entered at the bottom passed over each she order before it escaped through vent holes in the roof. The temperatu the oven was regulated by means of a gas pressure regulator "Mod see Fig. 50 (described in paper by E. Stansfield read before the Fa Society, May 2, 1914

It was found to be quite impossible to be consistent in the use of u some chemical apparatus is graded and catalogued in metric units b dealers, and other in British units. It was not thought necessary to giv equivalents in each case, as the units given in this report are those in common use for that particular case, e.g., an 18 mm. bore combustion t referred to, and so is a 6" U tube. Chemists use metric weights measures almost exclusively; but results which are to be emplo engineers are ordinarily reported in British units.

When portions of coal samples required for any determination are weig from a bottle into a counterpoised scoop, a pre-determined weight (e.g. 1 can be taken; but there is a liability to moisture change in the sampl weighing, and, especially with coals high in sulphur and ash, there is d of the heavier material accumulating towards the bottom of the sample b so that a representative portion is not obtained. If the sample is mixed sheet of paper before removing a portion for an analysis the latter da obviated, but the liability to moisture change is greater; and as the sample is thus exposed to the air each time a portion is removed for anal the difference between the moisture content of the first and last portions take may be considerable. It was in order to overcome the above difficulties that the method of filling a large number of specimen tubes with the sample was adopted. The sample was well mixed, as already described, and each tube was filled with a thoroughly representative portion; a fresh tube wa ed for each determination, and its contents were weighed out without apprecia exposure to the atmosphere. When a portion of a coal sample was re for an analysis, a suitably sized sample tube of it was taken, wiped wit duster, weighed, the coal emptied into the crucible or vessel in which it w wanted, and the tube at once re-corked and re-weighed, the differe in weight giving the exact weight of coal taken; it was, of course sible to take a predetermined weight of the sample. The above method w used for all regular coal samples; but for coke and ash samples, and less important coal samples, the usual method of weighing from a b a counterpoised scoop was employed. To avoid the repetition of tions, the phrase "one gram of the sample was taken" has been us report to cover both the weighing of exactly one gram in a scoop, and the us the contents of an approximately one-gram sample tube; the exact weig the latter was, of course, employed in making the necessary calculati the determination in question.

PLATE LIV

Drying apparatus, chemical laboratory — Department of Mining and Ore Dressing, McGill University



Model A.

M[illegible] B

[illegible]

When a fuel is burned in an ordinary calorimeter the products of combustion are cooled down to ordinary temperatures, and thus give up all their readily available heat. In a steam boiler or gas engine the products of combustion always escape at a temperature above that of boiling water; there is thus wasted not only the sensible heat of the gases but also the latent heat of vaporization of any steam present. The sensible heat wasted will vary with the conditions, but, as the latent heat of the steam produced is a definite and quite considerable amount and is almost inevitably wasted, it is often subtracted from the calorific value of the fuel, the result being called the net or lower to distinguish it from the determined calorific value which is called the gross or higher. The gross calorific value of a fuel can be defined as the heat evolved by the complete combustion of unit weight (or volume), when the products of combustion are cooled to water, etc., at ordinary temperatures; the net calorific value is the heat evolved by the complete combustion of unit weight (or volume), when the products of combustion are cooled to water vapour, etc., at ordinary temperatures. Throughout this report the gross values only are given, except in the case of calorific values of gases calculated from analysis where both values are given. If the latent heat of steam at ordinary temperatures is taken as 596 calories per gram (or 1073 B.T.U. per pound), then 6 calories per gram (or 11 B.T.U. per pound) have to be subtracted from the gross calorific value of a coal for each per cent of water it contains when burned, and 53 calories per gram (or 96 B.T.U. per pound) for each per cent of hydrogen it contains (other than hydrogen in the water) in order to obtain the net calorific value.

An example will show the method of calculation, and the magnitude of the correction which may be expected.

Coal No. 14, when dry, contains 4·8 per cent hydrogen and has a gross calorific value of 6750 calories per gram. As fired into the boiler it contained 7·3 per cent of water; its hydrogen content was, therefore, $4\cdot8 \times \frac{100 - 7\cdot3}{100}$ that is 4·5 per cent (not counting the hydrogen in the water), and its gross calorific value $6750 \times \frac{100 - 7\cdot3}{100}$ that is 6258 calories.

Correction for water in coal is $7\cdot3 \times 6$ = 44 calories
" " hydrogen in coal is $4\cdot5 \times 53$ = 239 "

Total correction. . . . . . 283 calories

$6258 - 283 = 5975$

The gross calorific value of the coal as fired into the boiler is, therefore, 6260 calories, and the net value 5980 calories per gram, or $4\frac{1}{2}$ per cent less.

For solid fuels, calorific values are given both in calories per gram and also in British Thermal Units per pound; for gaseous fuels, they are given in British Thermal Units per cubic foot of the gas measured moist at 60°F., and under a pressure of 30" of mercury.

The current International Atomic Weights have been used throughout the work (oxygen = 16·00.)

MOISTURE.

A porcelain crucible or capsule was ignited, cooled, and weighed, one gram of the sample was taken and placed in the crucible, which was then heated in a hot air oven to 105°C. (221°F.) for one hour At the end of the hour the crucible was transferred to a desiccator, wher it was allowed to cool over strong sulphuric acid; when cold it was agai weighed, being covered during weighing by a counterpoised watch glas The difference between the final weight and the sum of the original weight of the crucible and the coal or coke, is the loss in weight due to the wat having been driven off, and from this the percentage of moisture in the sampl can be calculated.

FIXED CARBON AND VOLATILE MATTER

The volatile matter in coal was determined by heating one gram the sample in a 20 c.c. platinum crucible having a well fitting lid, seven minutes over the full flame of a Chaddock porcelain burner; the l in weight gave the volatile matter. The crucible was supported by a pl inum triangle resting on the top of a fireclay chimney, the triangle be about 9 cm. above the orifice of the burner; the crucible was surround by an iron chimney, lined with asbestos, 3·4 cm. high and 7 cm. diamet The free flame of the burner was about 20 cm. high, the air supply bei so adjusted that the inner cone of the flame just did not touch the crucil the outside of the lid always burnt clean, but the inside was left covered wi carbon.

Fixed carbon was calculated by subtracting from one hundred the su of the percentages of volatile matter and ash.

The above method is practically that recommended by the America Chemical Society, except that dry coal is here used instead of undried co it was not until 1909, two years after the above method was adopted, th the method of the American Chemical Society was given internati recognition. The latter method is described as follows: "Volatile C bustible Matter—Place one gram of fresh, undried, powdered coal i platinum crucible, weighing 20 or 30 grams and having a tightly fitting cover. Heat over the full flame of a Bunsen burner for 7 minutes crucible should be supported on a platinum triangle with the botton 8 cm. above the top of the burner. The flame should be fully 20 c when burning free, and the determination should be made in a plac from draughts. The upper surface of the cover should burn clear b under surface should remain covered with carbon. To find the 'V Combustible Matter' subtract the percentage of moisture from t found here."[1]

The above methods are not suitable for samples high in volatile such as lignites or peat, as the rapid escape of gases causes solid matter to be thrown out of the crucible. Lignites were given seven minutes heati actly like coal samples, except that the heating was very gentle at firs most of the volatile matter had been driven off. A few coals exploded when heated by the regular method and so had to be treated like lignite.

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[1] Jour. Am. Chem. Soc., Vol. XXI (1899), p. 1122.

The above methods are also unsuited for coke, which does not generate sufficient gases to exclude the air from the crucible during the heating process; there is, in consequence, an inevitable loss of coke by oxidation, which loss must not be credited to volatile matter. A number of methods, old and new, were tested. The results of these tests are given in Appendix V, Vol. VI, the one finally adopted is as follows: -

A porcelain boat was ignited, cooled, and weighed, and filled with coke ground to pass an 80 mesh screen; it was then dried in an oven for an hour at a temperature between 105° and 115°C., cooled, and re-weighed; the increase in weight being the weight of dry coke taken. The boat was then ignited for 15 minutes, at a temperature of approximately 900°C. in an atmosphere of nitrogen in a platinum combustion tube. When cold, the boat was re-weighed, and the loss in weight taken as volatile matter.

The platinum tube was about 12″ long and ½″ diameter, it had long platinum caps at each end to which rubber tubing could be attached. A twenty-burner combustion furnace was used for heating, only those burners which were under the tube were lit and the taps for these burners, having been once adjusted to give a suitable flame, were never altered; the gas pressure at the furnace was kept at 1·6″ by means of a Stansfield pressure regulator, Model B, See Fig. 50. The temperature to which the tube was heated under these conditions was determined by means of a Morse optical pyrometer to be approximately 900°C.: 1″ gas pressure gave a temperature of 810°C. and 2″ gave 922°C. The ends of the tube were protected from the flames by passing through pieces of asbestos, and the caps were kept cool by a strip of cloth wrapped round them down which water was slowly siphoning from a small bottle. The porcelain boats were 4″ long and ¼″ wide and held about 0·6 gram of coke; larger boats would have been better, but these were the largest procurable that would go into the platinum tube. The nitrogen was generated by heating a solution of equal weights of sodium nitrite and ammonium chloride, and was stored in a large copper gas holder weighted to give about 5″ of water pressure. The nitrogen was purified by passing over yellow phosphorus and through strong sulphuric acid; any oxides of nitrogen present were removed by a spiral of reduced copper placed in porcelain boat at the front end of the platinum tube. In each experiment two boats containing dry coke and a smaller boat containing the reduced copper were placed in the tube; a moderate current of nitrogen was passed in for two minutes, the gas escaped at the back end through a glass tube which dipped under the surface of strong sulphuric acid. The nitrogen current was then reduced to a very slow stream and the furnace lit; at the end of fifteen minutes the heat was cut off and the tiles of the furnace opened to allow the tube to cool; ten minutes later the nitrogen was stopped altogether and five or ten minutes after this the porcelain boats were cold enough to take out and weigh. The copper spiral was as a rule partially oxidized, so it was reduced afresh between the experiments by being heated to redness and dropped into a test-tube containing a few drops of alcohol.

ASH

One gram of the sample was taken and put into a previously weighed crucible, which was placed in a gas-fired muffle furnace and heated, gently at first and then more strongly, until it became a fairly bright red. One hour heating was usually sufficient to burn the coal; but to ensure complete combustion two to three hours heating was generally allowed. The muffle had a hole at the back and the door was left slightly open during the process. The crucible was then transferred to a desiccator, cooled and weighed; the weight of ash left was thus determined.

In the case of samples of refuse (ash and clinker) from boiler or producer trials, the same procedure was followed; but in this case the percentage loss due to the ignition of the sample in the muffle, was reported as combustible matter in refuse.

The amount of ash was sometimes also determined by burning the coal in a crucible over a Bunsen burner; the muffle method, however, was preferred as the results seemed more reliable, twelve crucibles could be heated at once, and the initial heating was more easily regulated, so that there was less risk of coal being blown out of the crucible by too sudden combustion.

CARBON AND HYDROGEN

The usual method was adopted for the determination of carbon and hydrogen in coal. A weighed quantity of coal is burnt in a current of oxygen in a hard glass tube heated in a combustion furnace, the products of combustion are then passed over strongly heated copper oxide to complete their oxidation and over gently heated lead chromate which retains the sulphur. The water and the carbon dioxide thus produced are collected in suitable absorbents and weighed. The weight of the hydrogen in the coal is calculated as 0·1119 (log.=1·0487) times that of the water produced, and the carbon as 0·2727 (log.=1·4357) times the carbon dioxide.

Two important modifications of the general method were employed; the first of these modifications was practically that adopted by Prof. N. W. [illegible] for the work of the U. S. Coal Testing plant at St. Louis.[1] A twenty-five burner Bunsen combustion furnace was used to heat a Bohemian or hard glass combustion tube about 100 cm. long and 20 mm. outside diameter in which there were, beginning from the outlet end (where the products of combustion leave the tube): (1), a loose plug 1½ cm. long formed by a spiral of copper gauze placed 6 cm. from the end; (2), 14 cm. filled with lumps of fused lead chromate; (3), a second copper gauze plug; (4), 35 cm. of the wire form of copper oxide; (5), a third copper gauze plug, after which was a space of 38-40 cm. at the inlet end in which was a spiral of copper gauze about 5 cm. long. The tube projected about 10 cm.

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[1] U.S. Geol. Survey, Prof. Paper 48 (1906). p. 184.

beyond each end of the furnace and was closed at both ends by well fitting, single bored, rubber stoppers which were protected from the heat of the furnace by asbestos screens. Oxygen and air were supplied from gas holders and were purified by passing through a Traubers drying apparatus which consisted of a wash bottle containing strong sulphuric acid, another containing a one to one solution of caustic potash, and a 13″ U tube the first limb of which was filled with granulated soda lime and the second with granulated calcium chloride; this purifying train was in duplicate so that oxygen could be passed through one half and air through the other. The two halves were connected by a T to a glass stop-cock tube, one end of which passed through the rubber stopper into the inlet end of the combustion tube.

The absorption train at the outlet end of the combustion tube consisted of a 6″ Marchand U tube filled with calcium chloride to absorb moisture, and a Geissler or a Geissler-Wetzel potash bulb, with guard tube containing soda lime and calcium chloride, to absorb carbon dioxide. After the Marchand U tube had been filled with calcium chloride, the open limb was sealed off and a stream of carbon dioxide passed through it for an hour in order to convert any oxide present into carbonate; the carbon dioxide was swept out with dry air before the tube was used. One side tube was passed through the outlet cork of the combustion tube, a bulb between this and the limb of the U tube caught most of the water produced, and as this was shaken and boiled out of the bulb at the end of each experiment, one filling of calcium chloride (about 35 grams) lasted for a large number of determinations; the other side tube was connected with the potash bulb by rubber tubing, which was wired on during each experiment. The potash bulb was filled afresh for each experiment with a solution of two parts of caustic potash in three parts of water. The U tube and potash bulbs were fitted when not in use with end caps of rubber tubing with glass rod plugs, they were weighed before and after every experiment and were left at least a quarter of an hour in the balance case before each weighing; the caps of the tube or bulb were removed, the ends where the rubber caps had been, carefully wiped with a clean duster, and the whole brushed with a camel's hair brush just before they were put on the pan of the balance. Sometimes they were weighed alone and at other times each was weighed against a similar dummy tube or bulb on the other pan and the difference in weight recorded.

The absorption train was followed by a final guard tube of soda lime and calcium chloride which was connected to a Marriott bottle that supplied a constant head of suction. The suction was adjusted to be nearly but not quite sufficient to draw air through the whole apparatus, air or oxygen was then supplied to the purifying train under slight pressure so that it could pass through the whole apparatus, and as the interior of the combustion tube was under slight suction there was less danger of leaks than if it had been under pressure. When the absorption train was not in position the guard tube was used to protect the outlet end of the combustion tube.

Before any experiments were made with a combustion tube it was strongly heated and a stream of oxygen passed through it in order to burn out any organic matter from the tube or its contents. The whole apparatus wa also carefully tested for leaks.

In an actual experiment that part of the tube containing the coppe oxide was heated to a bright red, with the exception of the first few centimetr which were left cool, the part containing the lead chromate was heated t a barely visible red. Meanwhile the calcium chloride tube and potash bul of the absorption train were weighed and set aside, and a platinum or porcelai boat, which had been ignited and cooled, was weighed and about 0·2 gra of the sample to be analysed introduced into it as follows: the sample tube containing the coal was weighed and a suitable amount of coal poured out into the boat which was resting on a cork which had a groove cut to fit the boat and was covered with tin foil; the tube was at once recorked, the boat put into a desiccator and the tube then re-weighed, the difference in weight was the exact weight taken for analysis. When the combustion tube was properly heated the absorption train was connected up to the outlet end, the inlet cork was taken out, the copper spiral temporarily removed and placed on a clean watch glass, and the boat of coal introduced and pushed nearly up to the plug confining the copper oxide; the copper spiral was then put back and the cork replaced. A very slow current of oxygen was then caused to pass through the whole apparatus; the burners at the inlet end of the tube were now lit up, but until the copper spiral was at a bright red heat no heat was allowed near the boat. The most critical part of the experiment is in the gradual heating of the coal in the boat to drive off the volatile matter. This must be done very slowly otherwise methane and other hydrocarbons may escape unburnt from the tube; the heating was done by progressively lighting the burners under the boat, approaching it from both sides before any burners immediately underneath were lit, the flames were kept very low at first and then turned up little by little, and finally, when the flames were full up, the tiles for this part of the furnace were closed one by one to further increase the temperature. At no part of the experiment, if properly carried out, should there be more than a gentle succession of bubbles through the potash bulbs. When all the volatile matter had been driven off, the oxygen current was slightly increased and maintained until the coke left in the boat was completely burned: the progress of the combustion could be watched by observing the glow in the boat; this was regulated in intensity by means of the oxygen and was never allowed to become at all bright as there might be fusion of the ash. The oxygen was cut off some five or ten minutes after the combustion appeared to be completed, and air was then passed through until air only was left in the absorption train: each cubic centimetre of oxygen unreplaced by air in an absorption tube causes it to weigh about 1⅓ tenths of a milligram too much. The air current was very gentle at first but was increased later; about a litre of air was drawn through in an hour. During the latter part of the experiment care was taken to see that any moisture which had condensed in the cool part of the tube by the outlet cork was driven on into the calcium chloride tube; if necessary that part was heated by means of a hot tile. The diffusion of water, etc., into the inlet end of the tube past the copper spiral, which was intended to stop such diffusion, was always prevented if possible; but if water did condense there it also was driven forward by means of a hot tile.

At the end of the experiment the burners under the inlet end were turned out and the tiles opened; the absorption train was disconnected and the caps put on the tubes which were then put in the balance case to stand before weighing; and the boat was taken out and put in a desiccator ready to weigh in order to determine the weight of ash left.

The furnace was then ready for another determination, and if meanwhile a second set of absorption tubes had been prepared and weighed, and another boat of coal weighed, it was commenced at once.

From one to two hours were taken in bringing the furnace up to full heat after the boat was introduced, oxygen was passed through for about an hour longer at full heat, and then air was passed through for another hour to sweep out the oxygen. Two complete combustions with one furnace took as a rule eight or nine hours, but with two furnaces it did not take much longer for one operator to make four determinations.

An analysis of lignite was found to require great care in the initial heating; with coke or even anthracite this could be hurried.

W. Pollard, of the Geological Survey of England and Wales, recommends that the boat should rest on a strip of platinum foil in the combustion tube; "this prevents any chance of its sticking to the tube, and diminishes the chance of any copper oxide adhering to it."

The plugs and diffusion spiral are described as being spirals of copper gauze; it will, of course, be easily seen that in use the copper is rapidly oxidized and that after a few experiments they will be almost entirely copper oxide, although retaining their original shape.

The oxygen used was supplied by the Dominion Calcium Light Co., of Montreal. It was prepared, chiefly for medical use, by heating potassium chlorate. Blank experiments were made on sugar to test the purity of the oxygen and the accuracy of the apparatus before beginning the regular series.

The second modification of the general method of determination of carbon and hydrogen differed mainly from the above in the following points:—

1). The oxygen and air were passed through the apparatus under pressur no suction was employed.

2.) The absorption train consisted of (a) a 5″ U tube packed with pumice stone soaked in concentrated sulphuric acid, after each experiment the tube was re-filled with acid and the excess poured off before the next experiment; (b) a U tube packed with small pieces of stick caustic potash; and (c) a guard tube of soda lime and calcium chloride.

3.) The purifying train was modified to match the absorption train; the order was caustic potash solution, calcium chloride, soda lime, and, lastly, concentrated sulphuric acid at the furnace end of the train

SULPHUR

Sulphur was determined in regular coal and coke samples by the Eschka method, and as a check on this, it was also determined in the rinsings from the bomb calorimeter; at first gravimetrically by precipitation as barium sulphate, but later volumetrically by the more rapid benzidine method. A few unimportant samples were treated by burning with sodium peroxide and afterwards precipitating the sulphur with barium chloride.

Eschka Process

The reagents required were: (1) Eschka mixture, composed of two parts by weight of light magnesium oxide and one part of sodium carbonate mixed well together. (2) A saturated solution of bromine water, made by putting bromine into a bottle of distilled water: more water can be added from time to time as long as there remains any liquid bromine in the bottom of the bottle. (3) Dilute hydrochloric acid, approximately five times normal (5N HCl) prepared by diluting the pure concentrated acid with its own volume of water. (4) Half normal barium chloride solution, which is a solution containing 61 grams of the crystallized salt per litre.

The determinations were as a rule carried out in batches of five or six and in addition a blank experiment was made with each batch. About 1½ grams of Eschka mixture were placed in a weighing bottle (3″×1½″) and one gram of the sample added; the contents of the bottle were well mixed by shaking and then placed in a No. 2 (30 c.c.) porcelain crucible the bottom of which had been lined with a little of the Eschka mixture. The weighing bottle was rinsed out with half a gram more of the Eschka mixture and the rinsings were spread as a covering layer over the contents of the crucible: the crucible was kept on a sheet of glazed paper whilst being filled so that anything spilt could be recovered. The crucible for the blank was filled with the same quantity of Eschka mixture but without any coal or coke. In order to save weighings, marks were kept on the weighing bottles to show the height to which they were filled with ½ gram and 1½ grams of the Eschka mixture. When a batch of crucibles was ready it was put into a cold, gas muffle furnace. The muffle was heated up to a dull red heat—greater heat would cause objectionable sintering or even fusion of the charge—and kept at that heat for about two hours; this time was usually sufficient to burn off the coal (or coke) completely, after which the crucibles were taken out and allowed to cool. The contents of each crucible were transferred to a 350 c.c. casserole and the soluble matter thoroughly extracted with distilled water; to do this about 75 c.c. of water were put into the casserole which was then heated on a hot plate until the water boiled, when it was taken off, the contents allowed to settle, and the clear solution filtered through an 11 cm. filter (C.S. and S. No. 597) in a long stemmed funnel, into a 400 c.c. beaker; more water was then put into the casserole and the boiling, settling, and filtering process repeated two or three times; the residue was still further washed with hot water until the total filtrate amounted to about 300 c.c. Ten c.c. of bromine water were added to the filtrate in order to oxidize any sulphide or sulphite to sulphate, and the solution was made acid by the addition of about 4 c.c. of the hydrochloric acid. The beaker was then heated on the hot plate and its contents kept very gently boiling until rendered colourless by the removal of the excess of bromine. The solution was allowed to cool slightly, 12 c.c. of hot barium chloride solution were added slowly from a pipette with a fine jet, the whole well stirred, and then left to stand in a warm place for at least an hour. The barium sulphate precipitate was filtered through a 9 cm. filter (C. S. and S. No. 589, white ribbon) carefully folded to fit a 2¼" funnel: the clear solution was poured off through the filter, hot distilled water added to the precipitate, which after stirring was allowed to settle, and the clear liquid poured through the filter; this process was repeated a number of times. The precipitate was then washed on to the filter: after all that could be moved by the jet of the wash bottle was on the filter, the beaker and stirring rod were thoroughly cleaned by alternately rubbing with a rubber tipped glass rod and rinsing on to the filter with water from the wash bottle. The precipitate on the filter was then washed with hot water until the water passing through no longer showed milkiness when dilute silver nitrate solution was added. The filter containing the barium sulphate was then folded up and put in a weighed platinum crucible, this was heated very gently until its contents were dry, rather more strongly until the filter paper was completely charred, and then to a bright red heat until ten or fifteen minutes after the carbon of the paper had been burned off; this ignition in an open crucible would ensure the complete reoxidation to sulphate, of any barium sulphide which might have been formed by the reducing action of the carbon of the paper on the barium sulphate. The crucible was then cooled and weighed: the increase in weight was the weight of the barium sulphate plus the filter ash. In the blank experiment the weight found was that of the barium sulphate produced from sulphur in the reagents or absorbed from the gas of the muffle furnace, together with the filter ash. The weight found in the blank experiment was subtracted from that found in the other determinations in the same batch. The weight of sulphur corresponding to this net weight of barium sulphate was calculated by multiplying the latter by the factor 0·1374 (log. 1·1378); from the weight of sulphur thus found in the coal, the percentage was easily calculated.

All weighing bottles, crucibles, casseroles, funnels, and beakers were numbered 1, 2, etc., or B, for the blank, and a record kept of the number of the sample corresponding to each number; great care was taken in all the transferences, filterings, etc., to see that everything was kept in order. Whenever possible the vessels were kept covered with watch glasses. Filtering was usually done on a special stand of adjustable height, made to hold seven funnels; but it was found that time could be saved without loss of accuracy by filtering the barium sulphate precipitate through a funnel passing through a cork in the neck of a tubulated bell jar in which a suction of about 6" of water was maintained by a water pump and a safety valve, although each determination was then carried on singly at this stage instead of the seven being filtered simultaneously. In order to prevent any possible p of the barium sulphate precipitate through the pores of the filters, the were prepared for use after they were put in the funnels by pouring a quantity of paper pulp into them, filling up w[illegible] water, and allowing to The paper pulp was made by cutting up a few of the No. 589 filter pap shaking them in a large bottle with a considerable quantity of wate thoroughly disintegrated.

Sulphur in Calorimeter Rinsings

The rinsings from the bomb calorimeter, when ready for the determinations to be made on them, were either neutral or alkaline had been previously titrated with sodium carbonate to determine acidity. They were filtered into a beaker and, in the gravimetric m they were made acid with 1 c.c. of hydrochloric acid (5 Norm heated, hot barium chloride solution was added and the determinatio pleted as described above.

For the volumetric determination by the benzidine method the f solutions were required (cf. F. Raschig. The Chemical Engineer V No. 2. June 1906, p. 76): (1) Benzidine chloride; 40 grams of be were well rubbed up with 40 c.c. of water, the pulp brought with water into a litre flask, 50 c.c. of concentrated hydrochloric acid gravity 1·19) added, water added to the mark and the whole th mixed; a brown solution was produced which was filtered if necessary per cent solution of hydroxylamine hydrochloride. (3) A standard of caustic potash, approximately tenth normal, the strength of whi pressed as the weight of sulphur, in the form of sulphuric acid, equi each cubic centimetre. (4) Phenolphthaleïn solution made by dis gram of the solid in 100 c.c. of 86 per cent alcohol.

The cold filtered calorimeter rinsings, which would have a volum 300 to 400 c.c., were made acid in the benzidine method with a f of dilute nitric acid; 10 c.c. of the hydroxylamine hydrochloride were added and 25 c.c. of benzidine solution diluted to 100 c.c. wi the solution was stirred and the beaker set aside for 15 to 30 minutes to silky, flaky precipitate of benzidine sulphate to settle. The precip filtered off, with suction, through two 5·5 cm. filter papers in a funnel of a size to just allow the filter papers to lie flat on the The suction was stopped just before the funnel was quite dry an cipitate left in the beaker was washed out on to the funnel wi the filtrate from this or a previous experiment; as the precipitate little tendency to stick to the glass a couple of rapid rinsings suffic pletely clean the beaker. The suction was again put on, and as s last of the solution had passed through the filter, the precipitate washed with a few cubic centimetres of cold water, and the suc stopped when the precipitate was just dry. The precipitate is p soluble even in cold water so that very little should be used and th through at once. Keeping the suction on too long causes the precipitate to contract to a dry, silvery skin which is only slowly attacked by the caustic potash in the subsequent titration.

The precipitate and paper were then transferred to a 200 c.c. Erlenmeyer flask, the funnel was wiped out with a little paper and any precipitate still left was rinsed into the flask with hot water; a little phenolphthaleïn was added, the flask closed with a rubber cork and violently shaken until the filter paper was thoroughly disintegrated. The cork and the walls were then rinsed down, and the solution in the flask titrated with the standard caustic potash solution; it was kept hot whilst the caustic potash was being added, and the end point was only reached when the pink colour produced was permanent on boiling.

The number of cubic centimetres of caustic potash solution required, multiplied by the weight of sulphur to which each cubic centimetre is equivalent, gave the weight of sulphur in the coal taken, from which the percentage could be calculated.

It is advantageous to employ three wash bottles for the above determination: one for cold water, one for hot, and one to contain some of the filtrate. One filtration can be carried out whilst the previously filtered precipitate is being heated and titrated in the conical flask.

By the benzidine method as above it is possible to determine the sulphur in a batch of seven calorimeter rinsings in three or four hours. The method appears to give consistent results. Five pairs of readings by the barium chloride and the benzidine methods gave the following differences: 0·11, 0·06, 0·02, 0·04, and 0·11, the latter method always gave the higher result. The percentage of sulphur determined in the calorimeter rinsings was always found to be slightly less than by the Eschka process; this was probably largely due to the sulphuric acid produced in the calorimeter attacking the lead gasket of the bomb: if the washing out of the calorimeter were delayed, or a fresh gasket employed, the difference was found to be greater than usual.

NITROGEN

Nitrogen was determined in all regular coal samples by the Kjeldahl method. In this method a definite weight of coal is dissolved in concentrated sulphuric acid with the addition of a little mercury, the nitrogen in the coal is thus converted into ammonium sulphate; the mercury is then precipitated as mercury sulphide, the solution made alkaline with caustic soda, and the ammonia thus set free distilled over into a definite quantity of standard sulphuric acid, part of which it neutralizes; the quantity of acid neutralized by the ammonia is determined by titrating the excess with standard caustic soda solution, and from this the weight of nitrogen in the coal can be calculated.

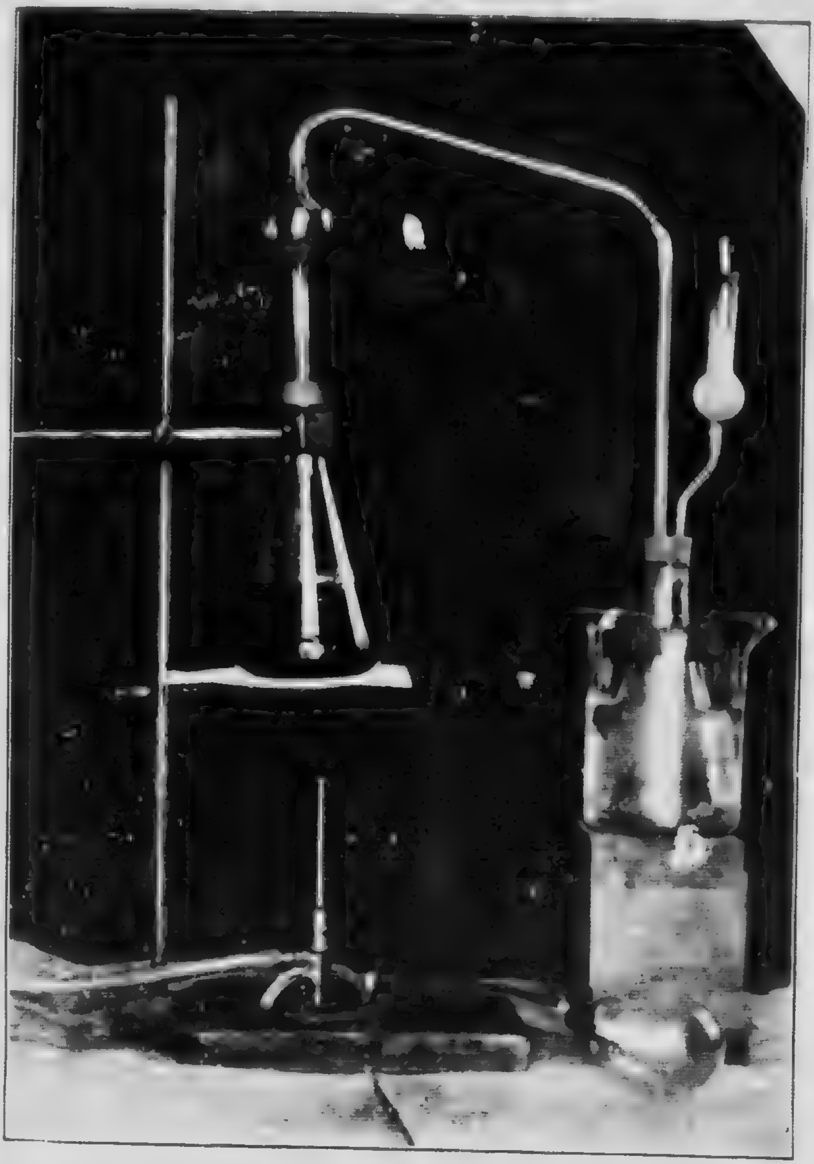
The following solutions were employed: (1) Concentrated caustic soda solution, 1,200 grams of soda to 2,000 c.c. of water. (2) Potassium sulphide solution, 40 grams per litre. (3) Cochineal solution, prepared by digesting

1 part of powdered cochineal with 10 parts of 25 per cent alcohol and
filtering (4) Approximately decinormal (0·1 N) sulphuric acid solution
(5) approximately 0·1 N caustic soda solution, the exact strength of which
been determined, and was recorded as the weight of nitrogen (as
to which each cubic centimetre of the solution was equivalent.

One gram of the coal was weighed out into a 200 c.c. Kjeldahl
a pear shaped flask with long neck a drop of clean mercury weighing
0·7 gram was added from a burette, the glass stop cock of which had
partially filled with plaster of Paris so that it delivered the correct
each complete revolution; 25 c.c. of concentrated sulphuric acid were
added, and the flask then heated to boiling over a small flame (without
interposition of wire gauze) in a fume cupboard. The mixture was
gently boiling until the fumes of sulphur trioxide were no longer
10 grams of potassium sulphate were then added in order to raise the
point of the mixture, and the whole kept boiling until the solution was
ally colourless: the average time taken to get the coal completely
was about 1¼ hours, but with high ash coals the product was always
dark in colour, however long the boiling was continued. The contents
the flask were then allowed to cool, sufficient water was added to
dissolve any salts that had crystallized out, and the solution
rinsed out into a 750 c.c. Erlenmeyer flask; 25 c.c. of the potassium sulphide
solution were then added to precipitate the dissolved mercury some fragments
of unglazed porcelain and a small lump of paraffin wax were added to prevent
bumping and frothing, and, when everything was in readiness to
with the distillation, 150 c.c. of the concentrated caustic soda solution were
added and the flask at once closed by the cork through which the
tube passed to the absorption flask (see Plate LV). The flask was then
heated and the contents kept briskly boiling until one-half had boiled
A large bulb splash head on the delivery tube caught any alkali
the boiling liquid and returned it to the distillation flask, the
ammonia passed through and along the tube which was bent
down through a two-holed cork into the absorption flask: the stem
tube filled with glass beads passed through the other hole in the cork.
the distillation was begun 25 c.c. of the 0·1 N sulphuric acid
down through the beads into the absorption flask and a little
solution also poured on the beads. The end of the delivery tube
within about half an inch of the surface of the acid in the flask
kept cool by being immersed in a water bath: any ammonia which
absorption by the acid in the flask was caught by the acid moistening
lower beads, and the cochineal always showed that the upper
beads at any rate, remained acid. When the distillation was finished
of the delivery tube and also the tube of beads were thoroughly
the absorption flask, and the excess of acid left in that flask was then
with the 0·1 N caustic soda; the cochineal present served as
titration.

From time to time, whenever any fresh reagent or solution was

Plate IV.



Kjeldahl nitrogen distillation apparatus. Chemical Laboratory, Department of Mining and Ore Dressing, McGill University.

a blank experiment was carried out; the number of cubic centimetres of caustic soda required in any determination subtracted from the number required in the blank experiment in which the same solutions were employed, gave the number of cubic centimetres corresponding to the ammonia produced from the nitrogen in the coal taken; this number multiplied by the weight of nitrogen to which one cubic centimetre of the caustic soda was equivalent gave the weight of nitrogen in the coal taken, from which the percentage could be calculated.

OXYGEN

As no method has yet been devised for the direct determination of oxygen in coal, the sum of the determined percentages of carbon, hydrogen, sulphur, nitrogen, and ash in the sample was subtracted from 100 and the result reported as the percentage of oxygen present.

This method throws upon the oxygen the sum of the errors of all the other determinations, not only errors of manipulation, etc., but also errors inherent to the methods employed. Various possible errors will be discussed more fully later, but as an example, a very common one may be given here. When coal contains iron pyrites (FeS_2), the sulphur is determined as such, but when the coal is burnt for the determination of ash, the pyrites becomes oxidized to ferric oxide, by absorption of atmospheric oxygen, so that the recorded weight of ash includes, besides the iron, the oxygen of the ferric oxide which was not in the coal at all; the reported percentage of ash in the coal will, therefore, be too great by this amount, and the percentage of oxygen, in consequence, too small.

Various possible corrections have been suggested; but it was felt to be advisable to keep to the simple method given above, rather than to adopt doubtful methods of correction. If it is clearly understood that "ash per cent" and "oxygen per cent" are conventional terms, representing results obtained in a certain standard way, rather than percentages of definite constituents of the original sample, then the chemical analysis of a coal loses little of its value as a guide to the nature of the coal, by reason of errors of the above character. Corrections are apt to introduce a personal element, which is undesirable, and also to give rise to an unwarranted feeling of accuracy of result.

The simple method adopted has also the great advantage that it is the one in most general use, in spite of the following recommendation made by the Committee on Coal Analysis of the American Chemical Society[1]:

"The method to be used in calculating the oxygen of the coal presents, perhaps, the question of greatest difficulty. If we could be sure that all of the sulphur is present in the form of pyrites, and that this is converted into ferric oxide in the ash, the oxygen should be found by subtracting from 100, the sum of carbon, hydrogen, nitrogen, ash, and $\frac{5}{8}$ of the sulphur. This is probably the safest rule which can be given for general use, and especially for coals high in sulphur. The operator should, however, satisfy himself as to whether the ash is practically free from sulphates, and, if possible, wheth the sulphur is mainly in the form of pyrites. If necessary, the rule should modified, in particular cases accordingly."

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[1] Jour. Am. Chem. Soc., Vol. XXI. p. 1129, 1899.

CALORIFIC VALUE OF SOLID FUELS

The calorific value of solid fuels was determined by burning a wei quantity of the fuel in an atmosphere of compressed oxygen inside a b immersed in water, and noting the rise in temperature of the water: the in temperature multiplied by the number of heat units required to raise bomb, water, containing vessel, etc., one degree (a number which is kn as the water equivalent of the calorimeter), gave the number of heat volved by the complete combustion of the sample taken

The bomb calorimeter used was an improved form of the Mahler in ment, made by Fritz Köhler of Leipzig. It consists of the following prin parts: (A) The bomb with accessories, pressure gauge, and conducting B) The calorimeter with three heat protecting jackets, mechanical and Beckmann thermometer.

The bomb, shown in section in Fig. 51, is a steel vessel of 275 c.c. cap tested to 300 atmospheres, with a screwed-on brass cover. The bomb is with enamel, the cover is plated on the inside with platinum to a thickn 0·2 mm., and the outside of both bomb and cover, and all the metal pa the calorimeter, are nickel plated. There are two openings through the into the bomb **S K** and **S**^{1} **K**^{1}, these can be closed by the needle valves c_1: c is the inlet valve through which oxygen is admitted to the bomb, oxygen passes down through the platinum tube **R** to the bottom of the bo so that all risk of the contents of the crucible **C** being blown out by a rush is obviated; c_1 is the outlet valve, it was usual to leave this open for a sho when the bomb was being charged with oxygen, in order that the ai bomb might be swept out. In the centre of the cover is an insulated st with a binding screw, this standard is connected with the platinum rod the bomb; the standard and rod are so arranged that, although they a ally insulated from the rest of the bomb, no gas can escape around them. the preliminary experiments trouble was caused by the heat of the com inside the bomb burning the electric insulation in spite of the prote mica washer; the mica washer was, later, protected and kept in positio against the cover by means of a heavy platinum washer screwed platinum rod. The platinum crucible or capsule **C** has a sleeve whi on the tube **R** and holds the crucible in the desired position. The other fuel in the crucible **C** was fired by a small fuse of fine iron wire passi from **Z** to **Z**$_1$, and having one or two loops in it which were arranged to the coal, the fuse was electrically heated by a current through wires co to the two binding screws **E** and **F**, the binding screw **E** was connected end of the wire fuse through the standard and rod insulated from the res the cover, and the binding screw **F** was connected to the other end of the through the valve **C**, the cover, and the tube **R**; the current was take

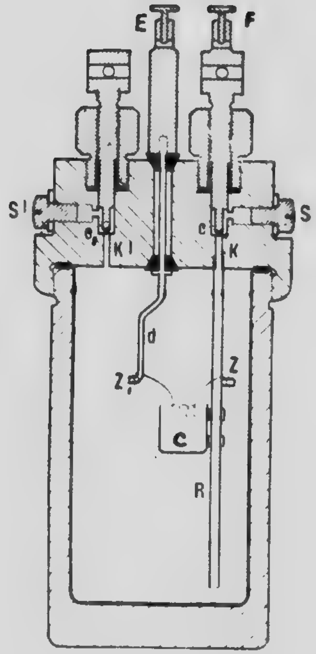


Fig. 51. Vertical section, Köhler calorimeter bomb.

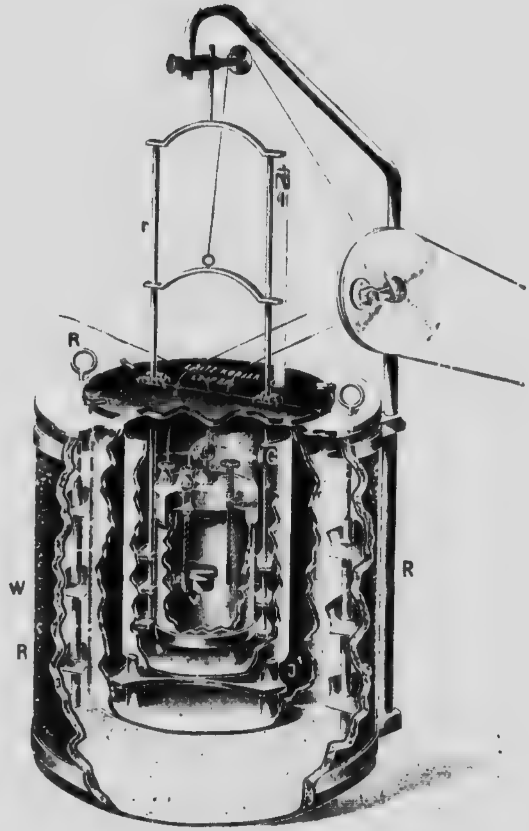


Fig. 52. Vertical section, Koëhler calorimeter.

a 110 volt supply and passed through two or three 32 candle power lamps —or their equivalent—arranged in parallel; this gave a current of 2 to 3 amperes which sufficed to almost instantly heat the wire fuse up to the temperature at which it caught fire and burned in the oxygen, and thus stopped the current. When the bomb was in the calorimeter the openings **S** and **S'** were closed with screw plugs. The junction between the bomb and its cover is made gas tight by means of a lead gasket or washer; care had to be taken to keep this clean and in good condition, and from time to time the gasket and the different screws were smeared with a trace of vaseline. The bomb has three pegs on the bottom, not shown in the figure, which fit into three holes in a special stand screwed down to the top of a table (see Plate LVI); when the bomb is placed on this stand the cover can be screwed down by means of a special double-ended spanner which fits over it. It is very undesirable to use excessive force when closing either the cover or the needle valves; if care is taken to keep these clean and in good condition, no great force is required.

The pressure gauge is graduated in kilograms per square centimetre (kg./cm^2.) —1 atmosphere = 1·033 kg. cm^2. The gauge was connected on the one side to a high pressure oxygen cylinder, and on the other it could be connected to the bomb, by capillary copper tubes fitted at the ends with suitable screw connectors.

The calorimeter is a nickel plated, brass vessel of about 5 litres capacity, with a stand inside, supported on three non-heat-conducting legs, on which the bomb can be placed. The calorimeter vessel itself also rests on three insulating legs in a much larger double-walled vessel; there is an air space between the calorimeter and the outer vessel, which latter has water between its double walls, is covered with a layer of felt, is closed with a vulcanite lid, and stands on three hard rubber legs. The general arrangement is shown in Fig. 52 where the stirrer in the outer jacket and the stirrer in the calorimeter can be clearly seen; the latter was raised and allowed to drop by being connected, by a piece of string passing over a pulley, to a crank driven by an electric motor; the rods of the stirrer pass between anti-friction rollers on the vulcanite lid, which allow the stirrer to move freely up and down, but prevent it from touching the walls of the calorimeter or bomb; each rod is made in two pieces connected by vulcanite sleeves to prevent the escape of heat along the rods. A small thermometer records the temperature of the water in the outer jacket, and a Beckmann thermometer, which is supported at a fixed height by a clamp (not shown), records the temperature of the water in the calorimeter vessel.

The Beckmann thermometer is made of Jena glass, and has a scale which reads from $-0·25°$ to $+ 6·20°$; each degree is divided into hundredths and the total length of scale is 24·6 c.m., so that with the reading lense, attached by a clip carrier to the thermometer, it is possible to read to the thousandth of a degree. The thermometer has a certificate from the Physikalisch-Technische Reichsanstalt (dated Aug. 21, 1906), which shows that the following corrections have to be applied:

(a). Calibration corrections in $\frac{1}{100}$ of a degree at 0° .0, at 1°. . .0, at 2°. . . + 2, at 3°. . . . + 3, at 4°. . . . . -18, at 5° -6, at 6° . 0

(b) Corrections for the mercury in the top bulb, etc., to different settings of the thermometer.

TABLE XLV

Recorded Temperature of Water in Calorimeter Vessel.

Setting of thermometer		Mean temperature of emergent portion of thermometer	Value of scale	
When 0 on scale corresponds to	0 C.	15 C.	1 B.	0·999 C.
When 0 on scale corresponds to.	10 C.	17 C.	1 B.	1·001 C.
When 0 on scale corresponds to.	20 C.	20 C.	1 B.	1·008 C.

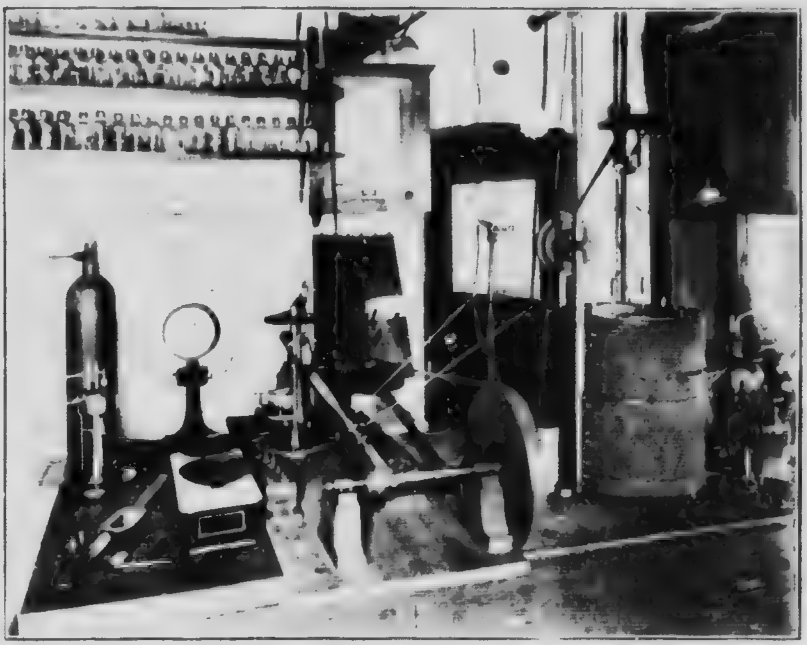
For intermediate temperatures and settings proportional correction were made. As the calibration corrections above 3° (Beckmann) are rath serious, the upper half of the scale was avoided. When the thermomet was in use a small electric buzzer was clamped on the top; the vibration p vented the mercury from sticking in the capillary and moving jerkily consequence

The briquetting press supplied with the calorimeter was modified that it could make a larger briquette in a shorter time; the coal briquett made were 6 mm. diameter and averaged such a length that four or fi weighed one gram. It was found possible to briquette every coal samp examined, but the anthracite coals and some of the lignites required to b ground very finely, and to be compressed as much as was possible with t small press.

The water put in the calorimeter vessel was measured and not weigh The measuring vessel used was a large bottle having a cork cemented in neck, through which passed an inlet tube for air and a delivery tube for wat the bottle was filled to a mark on the tubes half an inch above the cork, when being emptied it was always drained for about the same time delivered, under these conditions, at 15°C. 3549 grams, at 16°C. 3548 gra at 17°C. 3548 grams, at 18°C. 3547 grams, and at 19°C. 3546 grams of wa

The method of carrying out a determination was as follows: temperatures of the room and of the water in the outer jacket of the cal meter were adjusted, if necessary, to be within 2 or 3 degrees of each ot and the temperature of about four litres of water which had been put flask was adjusted to be about 1 degree cooler than the jacket wate the room temperature was greater than the jacket temperature, the of water would be made slightly less than one degree cooler than the ja and vice versa; the Beckmann thermometer was also re-set, if necess so that the temperature of the water would register on the lower part of scale. As a general rule the water temperature alone would need to adjusted. A piece of iron fuse wire was cut about 10 cm. long and weig a loop was made in the middle (round a piece of glass rod), and the two e twisted round **Z** and **Z**$_1$. The crucible, previously ignited and cooled, weighed, about a gram of the sample in the form of briquettes was introduced;

Plate LVI.



Koehler bomb calorimeter: general view. Department of Mining and Ore Dressing, McGill University.

it was then re-weighed and fixed to the platinum tube of the bomb in such a position that the loop of the wire fuse touched one or more briquettes. When the crucible and fuse were in position the cover was put on the bomb and screwed tight, the oxygen supply tube was connected to **S**, and, with the valves c and c_1 open, the valve of the oxygen cylinder was opened a little; after enough oxygen had been admitted to drive most of the air from the bomb the outlet valve was closed; when the pressure in the bomb rose to 22 kg cm as registered by the pressure gauge, the oxygen cylinder was closed, the inlet valve closed, the oxygen cylinder supply tube disconnected, and the two plugs **S** and **S**¹ put in; the bomb was then put into the calorimeter and two insulated copper wires, connected to the firing switch at one end, were connected to the binding screws on the bomb at the other end. Meanwhile the measuring bottle had been filled with water from the flask by means of a siphon; this water was then run into the calorimeter, the bomb was thus immersed except for the tops of the standard and the valve spindles. The lid was then put on the calorimeter, the Beckmann thermometer put in position, and the stirrer set in motion. About five minutes later the buzzer was started on the Beckmann thermometer, and thereafter readings were taken every minute to determine the rate at which the temperature of the water in the calorimeter was rising. If the rate of increase was found to be steady the firing switch was turned on after the sixth reading, and turned off again as soon as the lamps went out showing that the fuse had burned; if, however, the rise was not steady the readings were continued until it became so before the fuse was fired. For the first two minutes after firing readings were taken every half minute, and afterwards every minute until the expiration of five minutes after the temperature attained to a steady rate of change. The final steady period was usually reached five minutes after the firing. The first reading of this period was taken as the final temperature when calculating the rise of temperature of the calorimeter during the combustion period. The calorimeter was then taken out of the jacket, the bomb was taken out of the calorimeter, dried, opened, and thoroughly rinsed out with hot water into a beaker, and any fuse wire left unburnt was dried and weighed and readily detachable ash was removed from the crucible which was ignited and put in a desiccator to cool, the calorimeter water was returned to the flask, the different parts of the bomb and calorimeter were dried, and the apparatus was then ready for another determination. The rinsings from the calorimeter were titrated with standard sodium carbonate solution, methyl orange was used as indicator. One hour was sufficient for a complete determination, excluding briquetting the coal and making the necessary calculations.

The actual rise of temperature recorded during the combustion period that is from the time of firing at the end of the first steady period to the beginning of the second steady period—required to be corrected for heat transmitted to or from the calorimeter by radiation or conduction from outside; this radiation correction was calculated from the observed rates of change of temperature during the steady periods, it was kept as low as possible by the suitable preliminary adjustment of the temperatures of the water an jacket, etc., so that heat gained during the earlier part of the combusti period was neutralized by heat lost during the later part, when the tempe ture of the calorimeter had risen above that of its surroundings. Th recorded temperatures had also to be corrected for errors of calibrati of the thermometer, and the corrected rise of temperature converted to t equivalent degrees Centigrade by means of corrections found from thermometer certificate. The corrected rise in temperature, expressed Centigrade degrees, multiplied by the water equivalent of the calorime system, gives the total heat, in calories, generated by the combustion the bomb; in order to obtain the true calorific value of the fuel, this h to be corrected for accessory combustions; i.e., heat is given out by iron wire fuse in burning, nitrogen in the bomb is liable to be burn to nitric acid, and sulphur in the fuel, which normally, when burnin in air, burns to sulphur dioxide, burns in the compressed oxygen in the bo to sulphur trioxide which combines with water present to form sulphu acid, thus giving out an extra quantity of heat which cannot be legitima included in the calorific value of the fuel. The above accessory heats ha therefore, to be subtracted from the total heat, and the net heat thus fo divided by the weight, in grams, of fuel taken, in order to obtain the calo value of the fuel in calories per gram.

The methods employed for recording the readings and calculating the result of a determination are illustrated by the following example, to which explanatory notes have been added.:—

Method of Recording the Readings and Calculations of Determinations.

Dec. 7, 1907. Coal No. 1 (dry). Determination 1, Batch 1.

Crucible + coal	5·2290		0·0166
"	4·1808		0·0060

Coal No. 1 taken = 1·0482 grams. Fuse wire burned = 0·0106 grams.

Bomb: air swept out; charged to 25 kg./cm.²; slight leak.
Temperatures: water = 16 C., jacket = 16·88 C., room = 17·4 C.
Beckmann setting: 16·88 C. = 1·32 B., see note (a).

Time	Temperature readings		(d)	(e)
11 44 a.m.	0·153 (B)			
45	0·155			
46	0·156			
47	0·158	15 (b).		
48	0·159			
49	0·160			
50	0·162			
			15	
				6
½	0·98		·8	
				1
51	1·98		·4	
				+ 3
½	2·23		·8	
				4
52	2·26		·8	
				·8
53	2·26		·8	
				·8
54	2·262		·8	
				·8
55	2·262		·8	
56	2·261			– 0·0024
57	2·260			
58	2·259			
59	2·258	+ 8 (c)		
12.00 noon	2·258			
01 p.m.	2·257			

(f) 2·262 + 0·002 = 2·264
(g) 0·162 + 0·000 = 0·162

1·802
(h) 0·002

(i) 1·804 × 1·006

11

1·815 C.

(j) Total heat evolved: 1·815 × 4065 = 7378
(k) Fe: 1·06 × 17 = 18
HNO_3: = 17
H_2SO_4: 1·048 × 1·4 × 13 = 19 54

7324

Rinsings to beaker 1, 17c.c. required of the sodium carbonate solution.
All seemed well.

$$\frac{7324}{1·0482} = 6988 \text{ calories per gram.}$$

Explanatory Notes.

(*a*). Zero on the Beckmann scale, therefore, represents 15·5°C. and factor to convert degrees Beckmann into degrees Centigrade is, therefore, f the thermometer certificate, 1·006.

(*b*). This is the average fall of temperature per minute during the in period due to heat lost to (or gained from) the outside; it is expressed in thousandths of a degree on the Beckmann scale, and, as the temperature actually rising, it is negative in value.

(*c*) This is the average fall of temperature per minute during the period in 0·0001° B.

(*d*). This column gives the *rate* in 0·0001° B. per minute, at which calorimeter would get cooler, at each time the thermometer was read du the combustion period, on account of gain or loss of heat from or to the side. The assumption is made, in making this calculation, that the cha the rate of gain or loss is proportional to the change in temperature at the mean temperature of the first period (0·46°) the rate was -1 minute, at the mean temperature of the final period (2·26°) the rate was thus a change of 1·80° caused a change of rate from -15 to +8, tha total change of rate of 23; the rise in temperature from 0·46° to 0·98 recorded temperature at 11.50½ a.m., half a minute after firing) is 0·52 the change in rate would be $23 \times \frac{0·52}{1·80} = 7$; therefore, at 11.50½ a. rate of loss in temperature, due to gain or loss of heat from or to the out -15 + 7 that is -8. The other numbers in column (*d*) are similarly lated.

(*e*). This column gives the calculated *loss* in temperature of the meter, during each interval of the combustion period, due to gain o heat from or to the outside. The method of calculation is as follo rate of loss at 11.50 a.m., for example, was -15, half a minute later 8, the mean rate per minute during the period was -11½, but as th was only half a minute the actual loss for the period was half this -5¾ or approximately -6. The algebraic sum of the numbers in this gives the calculated amount by which the temperature of the cal at the end of the combustion period, is lower than it would have b heat had passed from or to the outside during the period: this is the radiation correction.

(*f*). This is the final temperature of the combustion period, which last from 11.50 to 11.55 a.m.; 0·002 is added, being the calibration corr the thermometer at that temperature.

(*g*). This is the temperature at 11.50 a.m., when the firing switch turned on; the calibration correction in this case is zero. Subtracting from (*f*) gives the actual rise in temperature.

(*h*). This is the radiation correction, calculated as above, which is added to correct for heat lost.

(*i*). The net rise in temperature thus found is converted into degrees Centigrade by multiplying by 1·006.

(*j*). The total heat generated in the bomb in calories is calculated by multiplying the net rise in degrees Centigrade by the water equivalent of the calorimeter system (4065 in this case).

(*k*). The thermal values given by different authorities for the reactions involved in accessory combustions, vary considerably; the corrections were made as follows

Iron —The number of centigrams burned was multiplied by 17.

Nitric acid: the rinsings from the calorimeter were titrated with sodium carbonate solution containing 3·706 grams of the anhydrous salt per litre, and the correction was made of one for every cubic centimetre of the solution required (the assumption was here made that all the acidity was due to nitric acid).

Sulphuric acid: a further correction was required for that portion of the acidity due to sulphuric acid: this was made by multiplying the weight of coal taken by the percentage of sulphur it contained (in the above sample 1·4 per cent) and multiplying the product by 13.

The above corrections (which are in calories) subtracted from the total heat, gives the total net heat from the combustion of the coal under normal conditions; this divided by the weight of coal taken gives the calorific value of the coal in calories per gram, which can be converted into British Thermal Units per pound by multiplying by 1·8.

All determinations of calorific value were made in duplicate, and only those checks that differed by less than 25 calories were considered satisfactory; when the combustion was complete, and no other obvious source of error noted, the disagreement was rarely as large as 25. In the earlier determinations about a gram of coal was taken; it was afterwards found that fewer failures and better agreement resulted if the weight taken was varied with the quality of the fuel so that a rise of from 1·5° to 1·8° C. was obtained.

The water equivalent of the calorimeter system was determined (*a*) by burning in it substances of known calorific value; (*b*) by weighing the parts and multiplying the weight of each constituent material of the system by its specific heat; (*c*) by adding a weighed amount of hot water of known temperature and observing the rise in temperature of the calorimeter; and (*d*) by generating electrically a known quantity of heat inside the bomb and observing the rise in temperature.

For the first of these methods napthalene, anthracene, benzoic acid, hippuric acid, and cane sugar were employed, but it was found to be more difficult to obtain consistent results with these substances than with coal, and the method was abandoned.

The second method involved estimating the weights of nickel plating, li ing enamel, etc., also the specific heats of the steel, brass, etc., from their pr able composition; part of the calorimeter vessel, stirrer, thermometer, et are not immersed in the water and so are not heated by the combustion the same extent, their water equivalent was, therefore, calculated separate and only one-third of it added to the water equivalent found for the rest the system. As the water required to immerse the bomb constitutes o 85 per cent of the water equivalent of the whole system, the possible err resulting in the calculation of the water equivalent of the remainder of system, due to errors in the above estimations and correction, can only a small percentage error of the water equivalent of the whole.

For the third method a special vessel was made from which the water was delivered into the calorimeter; it was of copper with a deli tube at the bottom closed by a spring valve actuated from the top. provided with a stirrer and thermometer, and was enclosed in an outer jacket to minimize radiation losses. The vessel was made of a size to allow it to stand on the lid of the calorimeter without interfering with the stirrer of the latter, and was arranged so that the delivery tube, which went through the hole in the lid through which one of the firing wires usually passed, should deliver the water without splashing into the calorimeter vessel. The calorimeter was set up as usual except that no coal or fuse wire were put in the bomb, and that a weighed amount of water was removed from the measuring vessel before its contents were poured into the calorimeter, so that when the hot water (from 300 to 400 c.c.) was run in, the final level of water in the calorimeter should be the same as usual. The amount of hot water run in was determined by weighing the containing vessel and accessories before and after. Cooling corrections were applied to determine the mean temperature of the water run in, and also, as usual, to the readings taken of the calorimeter Two experimenters were required to carry out this determination.

In the electrical method of standardization, the iron wire fuse bomb was replaced by a coil of platinum wire, the length and thick which was varied in different experiments. The apparatus was set usual, but the current was passed through an ammeter, and the across the terminals of the bomb was determined by a voltmeter. R of the calorimeter temperatures were taken every minute during the and final steady periods, and also during the heating period; readings ammeter and voltmeter were taken twice every minute during the to thirty minutes the current was passing. The current was varied in ent experiments from about four to nine amperes, and the volta thirteen to seven; these were, however, maintained as steady as during each experiment. It was found necessary to varnish the in standard of the bomb to prevent electrolysis of the water between the rest of the bomb, and it was found advantageous to have con oxygen in the bomb to accelerate the passage of heat from the heat to the walls of the bomb. The ammeter and the two voltmeters e were standardized in the Physical Laboratories of McGill University the direction of Prof. H. T. Barnes, and with the assistance of Dr. R. W. Boyle, and a table of corrections drawn up. If T is the time in seconds during which the current was passed, A the mean corrected value of the current in amperes, V the mean corrected value of the current in volts, R the corrected rise in temperature of the calorimeter in Centigrade degrees, and W the water equivalent of the calorimeter system, then the value of the latter is given by the equation:

$$W = \frac{A \times V \times T}{R \times 4 \cdot 188}$$

The weighing of the parts of the calorimeter gave as the water equivalent of the whole system—including the weight of water taken at the usual temperature employed, and also the oxygen in the bomb—the value of 4064 grams. The hot water method gave, as the mean of nine determinations varying from 4041 to 4083, the result of 4066 grams. The electrical method gave, in seven determinations, results varying from 4055 to 4070 with a mean of 4062 grams. It was decided to adopt the value of 4065 grams.

A new and heavier bomb was used for all determinations after Nov. 1908, the water equivalent of the system was then similarly determined as 4150 grams.

Fuller details of the method of use of a bomb calorimeter can be found in a paper by Atwater and Snell.[1]

CALORIFIC VALUE OF ASH FREE COAL

Ash free or ash and sulphur free coal do not exist, so that the calorific value of a coal calculated on either basis has a theoretical significance only, and has, probably, little commercial value. It was, however, thought worth while to calculate the calorific value of the ash free coal, in order to assist in the comparis[illegible] different raw and washed samples from the same seam. The meth[illegible]alculation consisted in multiplying the determined calorific value by [illegible], and dividing by 100 minus the percentage of ash in the sample.

CALORIFIC VALUE CALCULATED FROM ANALYSIS OF COAL

A large number of different methods have been suggested for calculating the calorific value of coal from its analysis; some of these calculations are based on the proximate analysis, and others on the ultimate analysis of the coal. The results from the proximate analyses often show wide divergences from the determined c[illegible]ic values; the results from the ultimate analyses are more reliable, but, as a calorimeter test is more rapidly and easily made than an ultimate analysis, and as few laboratories equipped to make ultimate analyses are not also equipped with at least a Parr or other simple form of calorimeter, if not with a bomb calorimeter, there seems to be little gained by making such calculations. The calculation was, however, made for all coal samples of which ultimate analyses had been made, and the results are given in the tabular statement. The formula adopted was that of Dulong, recommended by the Committee on Coal Analysis of the American Chemical Society (1899), which is the best known, though possibly not the most accurate

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[1] Jour. Am. Chem. Soc., Vol. XXV, No. 7, July 1903, pp. 659-699.

$8080\,C + 34460\,(H - \frac{1}{8}O) + 2250\,S$ — calorific value in calories per gram—where C is the weight of carbon in one gram of the sample, H the weight of hydrogen, O that of oxygen, and S that of sulphur.

FUEL RATIO

The fuel ratio of a coal, that is, the number obtained by dividing the percentage of fixed carbon in the sample by the percentage of volatile matter, gives considerable insight into the character of the coal; the higher the ratio the more the coal has changed from its original vegetable nature. The ratio varied in the samples examined from three-fourths in a lignite, to nearly seven, in an anthracite. The determination of volatile matter in coal can not be classed as an accurate determination, and any error causes an equal, but opposite, error in the fixed carbon, and, therefore, a larger error in the ratio of the two; no significance, therefore, should be attached to small variations in the fuel ratio, but, as stated above the ratio does give a general idea of the nature of the coal.

D. B. Dowling of the Canadian Geological Survey, has suggested a modified form of this ratio, which he calls the "Split Volatile" ratio.[1] He proposes a classification of coals for commercial purposes depending on the ratio, fixed carbon plus one half the volatile matter, divided by moisture plus one half the volatile matter; the analyses being made on an air dry sample. The claim is made that this ratio varies more in accordance with the heating value of the coal than does the ordinary fuel ratio.

CARBON HYDROGEN RATIO

Carbon and hydrogen are capable of very exact determination in coal, so that the ratio obtained by dividing the percentage of carbon present by the percentage of hydrogen, is one which can be determined with considerable accuracy. M. R. Campbell, in the report of the U. S. A. Coal Testing Plant at St. Louis, recommends the carbon-hydrogen ratio as the most satisfactory basis for the classification of coals; it should, however, be carefully noted that his figures are from analyses of air-dried coal, whilst the analyses and ratios given in this report are of dry coal. Drying the sample before analysis has the effect of raising the carbon-hydrogen ratio, this makes the most serious difference in the case of the lignites; the ratio could be easily re-calculated to the air-dry basis if desired.

For a further discussion of the above and other methods for the classification of coals from the chemical analysis, see the article by M. R. Campbell, referred to above.[2]

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[1] Report No. 1035 of the Geological Survey Branch of the Department of Mines, Canada, p. 43. See also Canadian Mining Journal, Vol. XXIX, p. 143, 1908.

[2] (U. S. Geol. Survey, Prof. Paper 48 (1906), pp. 156–173.)

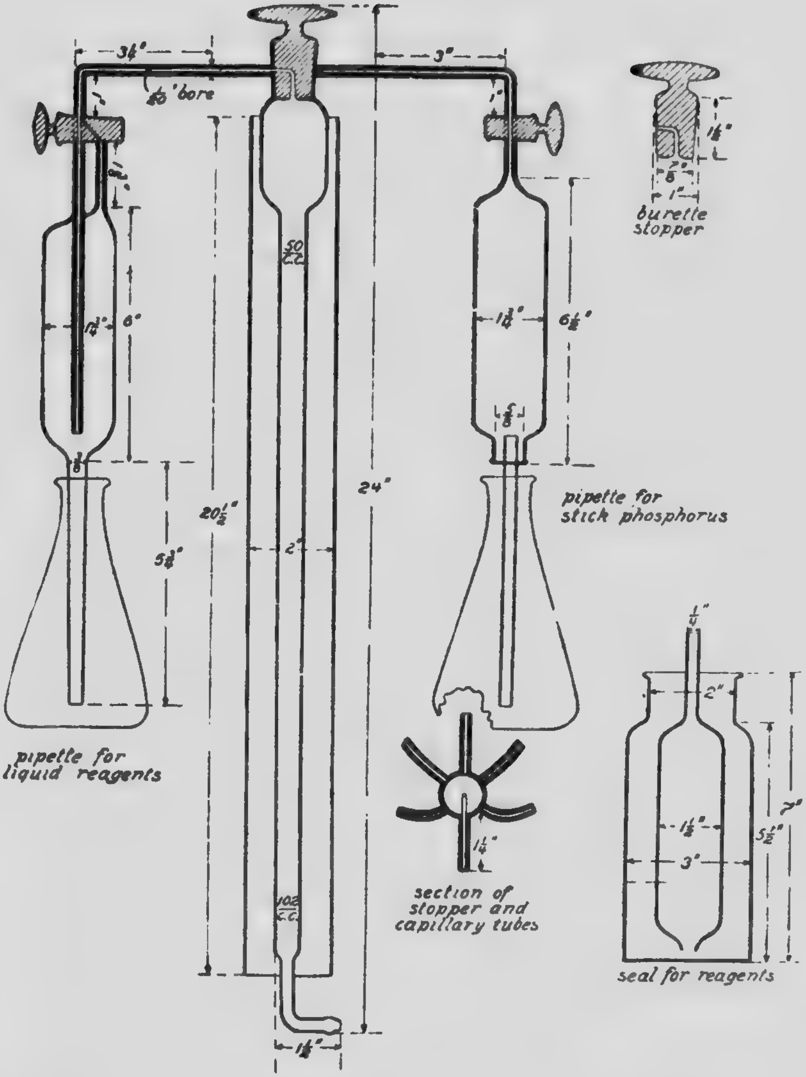


Fig. 53. Section of glass parts of Randall and Barnhart gas analysing apparatus.

GAS ANALYSIS

The constituents which are usually determined in the samples of producer gas, coke oven gas, etc., are: carbon dioxide, unsaturated hydrocarbons (of these ethylene is most important, and their total percentage, there being no ready means for determining them separately, is generally reported as the percentage of ethylene), oxygen, carbon monoxide, saturated hydrocarbons (usually almost entirely methane), hydrogen, and nitrogen. In flue gas samples, carbon dioxide, oxygen, carbon monoxide, and nitrogen are the only constituents determined. The first four gases mentioned above are determined by absorbing them successively by means of suitable reagents: a definite volume of gas (100 c.c. as a rule), measured under atmospheric pressure, is passed from the measuring vessel into an absorption pipette containing the first reagent to be employed; after sufficient time has elapsed for complete absorption the gas is brought back into the measuring vessel, and the reduction of volume at atmospheric pressure gives the volume of the constituent gas absorbed by that reagent. After the four absorptions have been completed the gas residue may contain methane, hydrogen, and nitrogen; a definite amount of this is taken, mixed with an excess of oxygen or air, and exploded in a vessel over mercury by means of an electric spark between two platinum points; the reduction in the volume of the gas, due to the explosion, is measured, and then the volume of carbon dioxide produced is determined by absorption in caustic potash. The reactions in the explosion are: –

(1). $CH_4 + 2O_2 = CO_2 + 2H_2O$
1 vol. + 2 vols. gives 1 vol. + 0 vol. of gas. Contraction = 2 vols.

(2). $2H_2 + O_2 = 2H_2O$
2 vols. + 1 vol. gives 0 vol. of gas. Contraction = 3 vols.

from which the following formulæ are deduced: –

Volume of methane = volume of carbon dioxide produced.

Volume of hydrogen = $\frac{2}{3}$ (volume of contraction less twice volume of carbon dioxide produced).

From the volumes of methane and hydrogen found in the quantity of gas residue taken, their percentages in the original sample can easily be calculated. If the gas is not rich enough to explode when mixed with oxygen, a little electrolytic gas is added to the mixture. Electrolytic gas is formed by electrolysing acidulated water, and is composed of hydrogen and oxygen in the proportions required to form water; as the electrolytic gas returns entirely to water when exploded, the addition of the gas makes no difference to the final volume after the explosion. The percentage of nitrogen is calculated by subtracting from 100 the sum of the percentages of the other constituents.

Gas Analysis with the Orsat-Muencke Apparatus.

The Orsat apparatus is too well known for any description of it to be necessary. It was only used for flue gas analyses during the summer of 1907. The absorbents employed were: (1) caustic potash to absorb carbon dioxide (2) an alkaline solution of pyrogallol (pyrogallic acid) to absorb oxygen and finally, an acid solution of cuprous chloride to absorb carbon monoxide; the two latter solutions required frequent renewals. The pyrogallol solution was made by dissolving 7 grams of the salt in 18 c.c. of water and placing the solution in the absorption pipette, a solution of 145 grams of caustic potash in 95 c.c. of water was then added, and the pipette at once closed

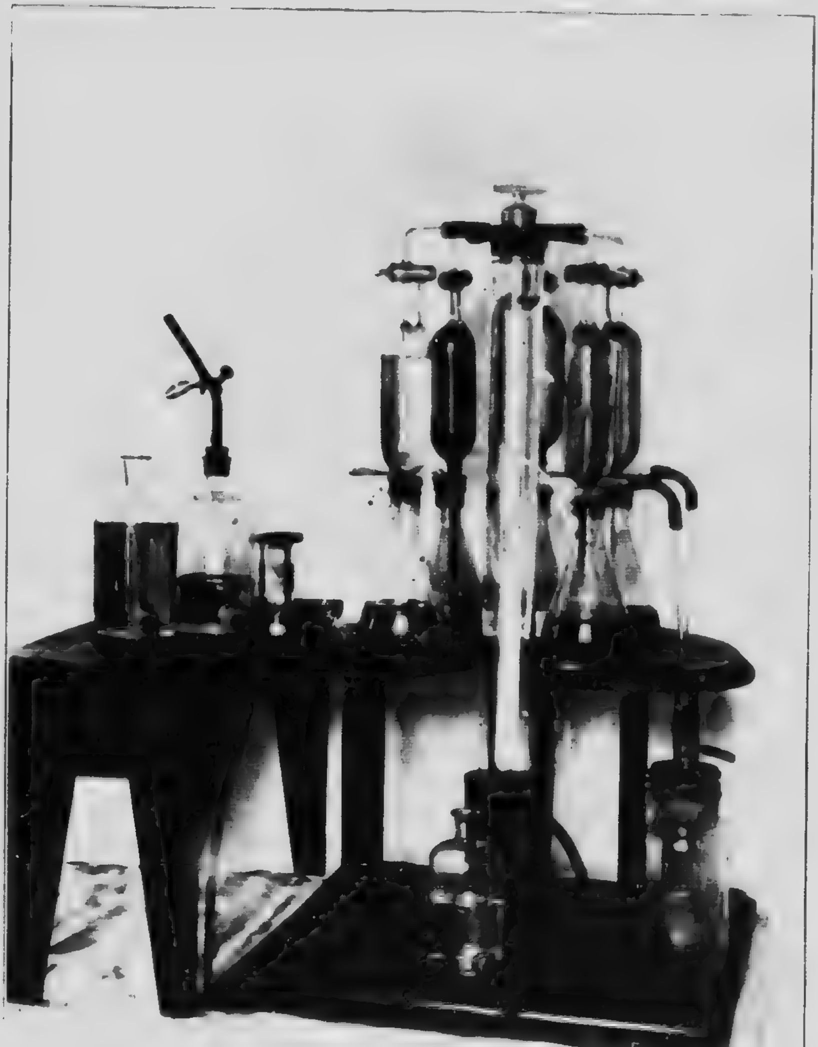
Gas Analysis with Randall and Barnhart Apparatus.

This apparatus was described by E. Barnhart in the Electrochemical and Metallurgical Industry, Vol. V (1907), p. 350. Fig. 53 shows the section of all the glass parts of the apparatus, and Plate LVII is from a photograph of the apparatus when set up.

The measuring burette is of rather more than 100 c.c. capacity; the narrow part is graduated in $\frac{1}{10}$ c.c. from 102 c.c. at the bottom to 50 c.c. just below the wide part, and has a white back with a blue strip to facilitate accurate reading. The bottom of the burette terminates in a narrow tube for rubber connexion with a levelling bottle, and the upper end in a wide neck which forms the casing for a six-way tap stopper. On the outer circumference of this casing are six capillary tubes 1½″ long, which each communicate with the burette when the stopper is in the proper position. Six pipettes can thus, if necessary, be in turn directly connected with the burette, so eliminating the long header capillary of the Orsat apparatus, and the necessity, as with the Hempel apparatus, for changing the pipettes during the process of analysis. The six-way stopper was kept well lubricated and never gave any trouble. The pipettes for liquid reagents are of the type in which the gas is forced to pass through the reagent; the pipette proper terminates in a narrow tube which passes through a double-bored rubber stopper into a 300 c.c. Erlenmeyer flask, which acts as a support for the pipette and a reservoir for the reagent, a second tube through the rubber stopper of the flask can if necessary, be connected to a very simple water seal standing on the baseboard of the apparatus. When gas was being passed into a pipette, the tap was first turned for an instant into such a position that the liquid was driven out of both capillaries leading into the pipette, the tap was then given half a turn and the gas thus forced to pass through the longer capillary and rise up through the liquid

The following reagents were employed as absorbents: (1) caustic potash solution, to absorb carbon dioxide; prepared by dissolving one part by weight of caustic potash in two parts of water. (2) Bromine water to absorb unsaturated hydrocarbons, such as ethylene; a saturated solution of bromine in water was used, sometimes about 5 per cent of potassium bromide was added to reduce the vapour pressure of the bromine; the gas

Plate LVII



Randall and Barnhart gas analysing apparatus: general view. Department of Mining and Ore Dressing, McGill University

was always returned to the potash pipette to remove bromine vapour, before remeasuring. (3) Sticks of yellow phosphorus to remove oxygen; these are made by melting yellow phosphorus under water and sucking it up into a piece of glass tubing of about $\frac{5}{16}$" bore, then cooling it, and forcing out of the tube by means of a glass rod; very great care must be taken in performing the above operation to avoid all risk of fire or poisoning. The phosphorus pipette was painted to protect the phosphorus from the action of light. (4) Ammoniacal cuprous chloride solution to absorb carbon monoxide: 15 grams of ammonium chloride were dissolved in 60 c.c. of water in the reservoir flask, 57 grams of cuprous chloride were added, and concentrated ammonia added with frequent shaking until the copper salt was dissolved, water was then added to fill the flask. This solution was always protected from the air by a water seal, the air in the pipette and in the seal was displaced by nitrogen or hydrogen when refilling the pipette. (5) Acid cuprous chloride to absorb any carbon monoxide not previously absorbed: 16 grams of copper oxide were dissolved by warming with 200 c.c. of concentrated hydrochloric acid, 100 c.c. of water were then added and 26 grams or more of copper in the form of turnings, wire, or gauze, and the whole heated and caused to gently simmer until colourless; the solution was then cooled at once and transferred to a water sealed pipette without air being allowed to come in contact with it: copper wire was kept in the reservoir flask of the pipette, and the solution was in this way kept colourless.

The above apparatus was used for nearly all producer gas samples, and for all the flue gas samples after the first summer.

The actual analysis was carried out as follows: the pipettes were each filled with their reagent, or with water in the case of the phosphorus pipette, to a mark just below the stop-cock, and the burette and its front capillary tube were completely filled with water. The aspirator bottle containing the sample (see page 127) was placed on a stand in front of the apparatus (the stand and sample bottle are shown on the left in Plate LVII); the rubber tube of the sample bottle was filled with water from the spring clip upwards, to displace the air from it, and was then connected to the front capillary tube of the burette. By suitably manipulating the various cocks and levelling bottles, approximately 102 c.c. of the gas sample were introduced into the burette, and the sample bottle and stand were removed. After the water had been allowed to drain from the walls of the burette for one minute, the levelling bottle was raised and the gas compressed to exactly 100 c.c., the rubber tubing at the bottom of the burette was then pinched with the finger and thumb to prevent change in volume, whilst the stop-cock was turned to bring the gas in the burette into momentary connexion with the outside air. As the gas was at more than atmospheric pressure, some would escape leaving 100 c.c. at atmospheric pressure in the burette. By suitably turning the stop-cocks and raising the levelling bottle, the gas was driven over into the caustic potash pipette, where it was left, with occasional shaking, for one minute. The gas was then returned to the burette and the reagent brought back to its original level in the pipette. After the water had been allowed to drain down in the burette for one minute the gas was brou to atmospheric pressure, by raising or lowering the levelling bottle until level of the water in it was the same as that in the burette, and its new vol read, the contraction was taken as the volume of carbon dioxide pres in the sample. The gas was then transferred to the second pipette, and so

The gas was left for one minute in the potash solution, one minu the bromine, three minutes in the phosphorus, three minutes in the cuprous chloride solution and two minutes in the second, and it was al left a minute in the burette before its volume was read. The abo for absorption were, however, varied slightly according to the fres and activity of the reagent, and the probable percentage of the cons to be absorbed.

The use of ammoniacal cuprous chloride followed by the acid so gave very satisfactory results; the ammoniacal solution has great ca for absorption, and the acid solution, which has a vapour pressure too to cause appreciable error, has normally only very small traces of absorb, so that both reagents will last for a large number of determin

Determinations of hydrogen and methane, in the gas residue lef the above absorptions, were made by explosion over mercury, usual Hempel pipette which could be temporarily attached to the front ca connexion of the burette; but, occasionally, the gas left after re carbon monoxide was transferred to a test tube over mercury, and analysis completed over mercury in the Bone and Wheeler apparatus. El lytic gas, prepared by electrolysing a dilute solution of sulphuric ac used to enrich the gas taken for explosion; the percentages of hydrog methane in producer gas are not, as a rule, high enough to enable th plosion to be made without such addition. The use of the Bone and W apparatus for the determination of hydrogen and methane, and the R and Barnhart apparatus for the determination of the other constitu the gas was found to be a very satisfactory combination, and rapid could thus be made with reasonable accuracy.

Water is not entirely satisfactory as the confining liquid for gas at as some gases dissolve in it to an appreciable extent; but the use mercury apparatus throughout would have involved extra work wh not thought to be commensurate with the increased accuracy to be a Although it is possible to use water with reasonable accuracy dur absorptions, it cannot be used during the explosion, as the carbon produced, at the high presure developed by the explosion, is dissolv considerable extent by the water; and a small loss of carbon d occasions a large error in the result.

The following example shows the method of calculating the res gas analysis with the Randall and Barnhart apparatus and Hempel ex pipette:

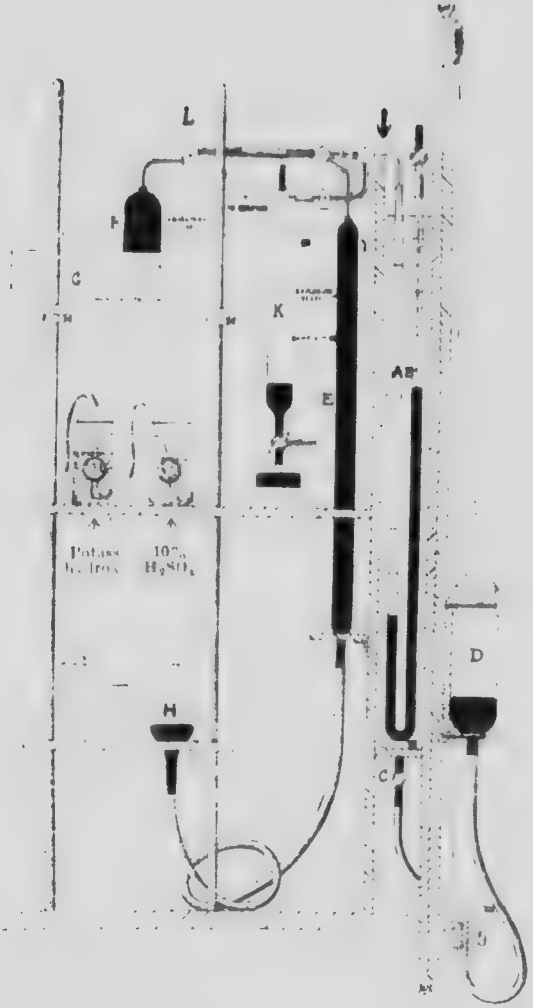


Fig. 51. Diagram of Bone and Wheeler gas-analysing apparatus.

TABLE XLVI

Analysis of Producer Gas, with Randall and Barnhart Apparatus.

Gas taken (Producer gas)	= 100·0 cc				
After potash	= 90·2 "	contraction	= 9·8 cc	Carbon dioxide	9·8%
After bromine	= 89·7 "	"	= 0·5 "	Ethylene	0·5
After phosphorus	= 89·1 "	"	= 0·6	Oxygen	0·6
After cuprous chloride	= 80·2 "	"	= 8·9 "	Carbon monoxide	8·9
Volume of gas residue taken for explosion	22·2 "				
After adding air	68·3 "				
After adding electrolytic gas	74·[illegible] "				
After explosion	62·0 "	contraction	6·3 "		
After potash	= 61·0 "	"	= 1·0 "	Methane	(a) 3·6
Contraction due to hydrogen = 6·3 − (2 × 1·0)		"	= 4·3 "	Hydrogen	(b) 10·4
By difference				Nitrogen	66·2
					100·0

Note (a) $1\cdot0 \times \frac{80\cdot2}{22\cdot2}$ $3\cdot6$

Note (b) $4\cdot3 \times \frac{2}{3} \times \frac{80\cdot2}{22\cdot2}$ $10\cdot4$

Gas Analysis with Bone and Wheeler Gas Analysis Apparatus.

This apparatus was described by W. A. Bone and R. V. Wheeler in the Journal of the Society of Chemical Industry, Vol. XXVII, Jan. 15, 1908, p.10. It was used for all coke oven gas samples, for a few producer gas samples and some miscellaneous gas samples, and also, as described above, to determine the methane and hydrogen in some producer gas samples after the other constituents had been removed in the Randall and Barnhart apparatus.

Fig. 54 gives a diagrammatic representation of the apparatus, and Plates LVIII and LIX show the apparatus as set up in the laboratory. The apparatus comprises, essentially, three parts, viz.: (1) a water-jacketed combination of measuring and pressure tubes, **A** and **B** communicating, through the glass tap, **C** with the mercury reservoir, **D**; (2) an absorption, or laboratory, vessel, **F**, standing over mercury in a mahogany trough, **G**; (3) an explosion tube, **E**, fitted with firing wires, and connected with a separate mercury reservoir, **H**. All the connexions between **A**, **E**, and **F**, are of capillary bore throughout, with suitable glass taps wherever necessary. The diagram also shows how connexion is made between the measuring tube, **A**, and the special sampling tube, **K**, whenever the latter is employed for the introduction of the sample under examination; in one photograph a small pipette containing sticks of phosphorus is shown in the place of the sampling tube **K**; an unsuccessful attempt was made to replace pyrogallol by phosphorus for the absorption of oxygen in this apparatus, but the power of the phosphorus to absorb oxygen rapidly diminished when mercury was used, instead of water, as the confining liquid.

Gas samples were generally introduced into the apparatus from an ordinary hard glass test-tube, under the wide, open end of the absorption vessel, **F**, which had been previously filled with mercury. Plate LX shows the special rack in which gas samples were stored over mercury, in test-tube standing in flat porcelain crucibles; the base of the stand had raised sides t prevent loss of mercury.

Before commencing an analysis, the whole of the apparatus, includin all connexions between **A**, **E**, and **F**, was completely filled with mercury, an all subsequent operations were conducted over mercury.

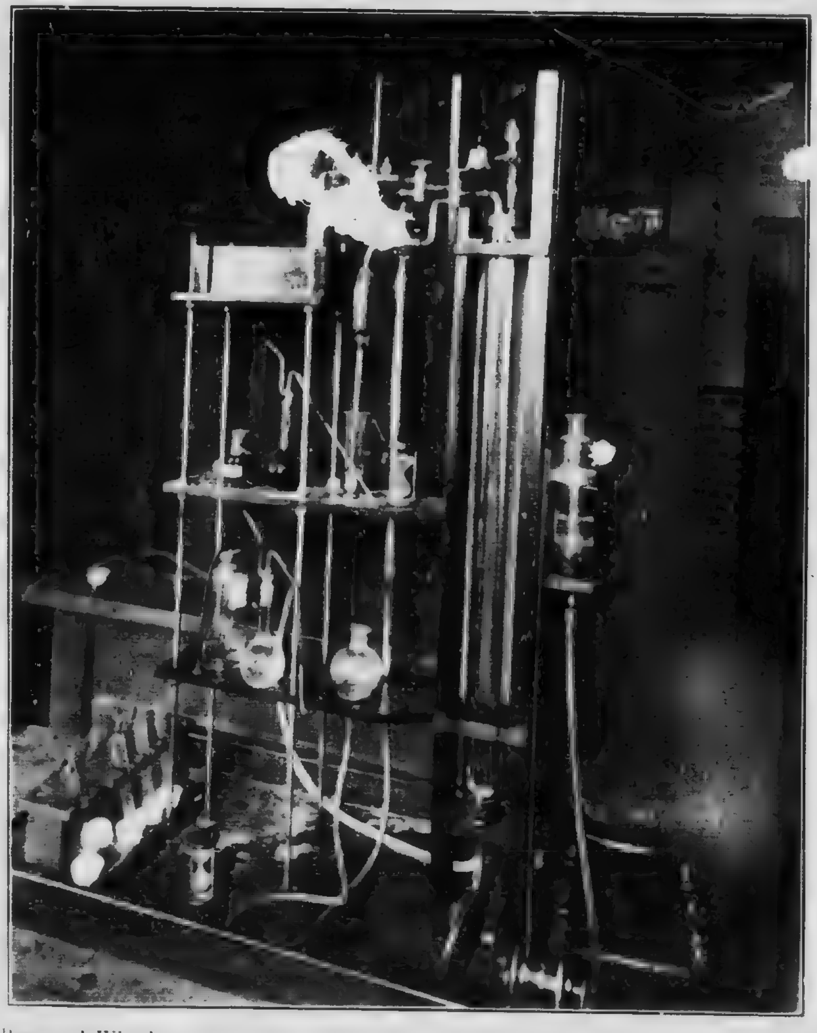
The various parts of the apparatus are mounted on a wood stand of teak, with four vertical steel rods supporting the shelf upon which the mercu trough, **G**, rests; the same rods also carry two other shelves for reagent bottl The mercury reservoir, **D**, can be raised or lowered (to the ground level, as required), in its wooden carrier, by means of a pulley with ratchet wheel and catgut cord. The whole apparatus stands in a wooden tray 2′-4″ × 1′-6″ with raised sides.

The salient features of the working of the apparatus are as follows:

(1). The principle of measurement employed is that of the measurement of the pressure of the gas (in mm. of mercury) at constant volume. For this purpose the gas is brought to a certain constant volume mark in the measuring tube, **A**, (by suitable manipulation of the mercury reservoir **D** and the tap **C**) and its pressure read off on the pressure tube, **B**. There are a series of such constant volume marks on **A**, coinciding in level with each hundred mm. mark on the pressure tube **B**, so that the actual pressure of the gas is given by subtracting from the pressure reading the numbers 0, 100, or 200, etc., according to the particular constant volume mark selected for the analysis. The tubes **A** and **B** are made in one piece and are surrounded by a water jacket, their inner surfaces are kept moist with very dilute sulphuric acid (1 in 20) as a precaution against the accidental fouling of the measuring tube with alkalies: it is obvious that the wetting of **A** and **B** with the same liquid eliminates the influence of water vapour upon the gas measurements, the various pressures representing those of the dry gas under examination. The tap closing the upper end of the pressure tube is connected with the latter by means of stout rubber pressure tubing, a device which gives a perfectly tight joint with sufficient elasticity to prevent fracture in case the mercury in **B** is inadvertently allowed to run up the tube with unusual velocity; the tap in question also allows the vacuum to be easily re-made in **B** whenever necessary. The advantages of this mode of measurement over the more usual method of determining the volume under atmospheric pressure are twofold: (a), it allows of the use of smaller volumes of gas, for an analysis—thus from 5 to 10 c.c. of gas can be made to have a pressure of about 100 mm., according to the particular volume mark selected, and this pressure can easily be read off to within 0·2 mm. without employing a telescope (readings are best made by means of a light placed behind the tube a little below the surface of the mercury (b), the measurements are independent of the barometric pressure and at the same time are unaffected by tension of aqueous vapour.

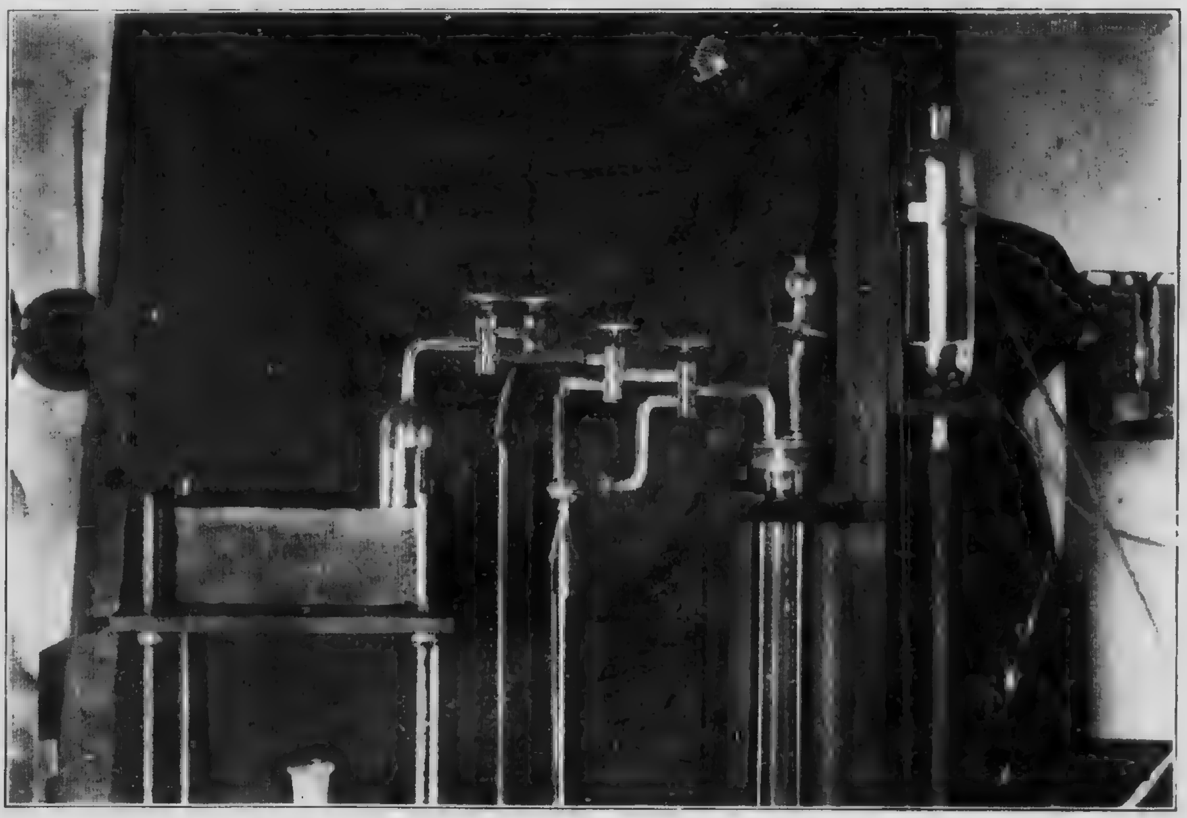
(2). The length of the pressure tube, **B**, (about 700 mm.) amply provides for the proper dilution of the explosive mixture in an explosion analysis, even in the case of a rich gas such as coal gas.

Plate LVIII.



Bone and Wheeler gas analysing apparatus: general view Department of Mining and Ore Dressing, McGill University.

Plate LIX.



Bone and Wheeler gas analysing apparatus: details. Department of Mining and Ore Dressing, McGill University.

(3). The arrangements for the various absorptions are simple. Instead of using a number of large absorption vessels each containing a particular reagent, which is used unchanged many times over in successive analyses, all the absorptions are carried out over mercury in the one absorption vessel, **F**, in each case with a comparatively small volume of the particular reagent, which is always used fresh and is at once discarded after use.

To facilitate the introduction of the various reagents, and the rinsing out of the absorption vessel with water or dilute sulphuric acid *in situ* between each successive reagent, the wide, open end of the vessel is immersed in the mercury in the trough, **G**, whilst the top terminates in a capillary three-way tap, **L**. One of the parallel branches of this tap communicates, through a stout rubber joint, with the measuring vessel, **A**, and the other with a large exhausted bottle which serves to catch the discarded reagent and any mercury which also passes out. The bottle is re-exhausted from time to time by means of a water jet suction pump.

From 2 to 10 c.c. of the particular reagent to be used are introduced into the absorption vessel (previously filled with mercury) by means of a pipette with a curved jet, from below the surface of the mercury in the trough. Any bubble of air accidentally introduced with the reagent can be got rid of by cautiously opening the branch of the tap, **L**, leading to the above-mentioned, exhausted bottle. The gas can now be brought from the measuring vessel to the "laboratory" or absorption vessel **F**, and shaken with a previously introduced reagent. When the absorption is complete the gas is passed back to the measuring vessel, the tap **L** is turned as soon as the reagent reaches it so that the reagent passes out into the exhausted bottle; the laboratory vessel is then rinsed out with dilute acid and the rinsings also withdrawn, the tap **L** is then cautiously turned to connect the laboratory vessel with the measuring tube and the cleaned mercury allowed to flow from the laboratory vessel along the connecting tubes towards **A** until it reaches the point indicated by the arrow, the tap immediately behind this point is then closed, the gas brought to its original constant volume mark in the measuring tube, and the new pressure read: the difference between the new and the old pressures is a measure of the volume of gas absorbed by the particular reagent. A fresh reagent can now be introduced into the laboratory vessel and the process repeated. The oxygen and electrolytic gas required for the explosion are also introduced into the apparatus through the laboratory vessel.

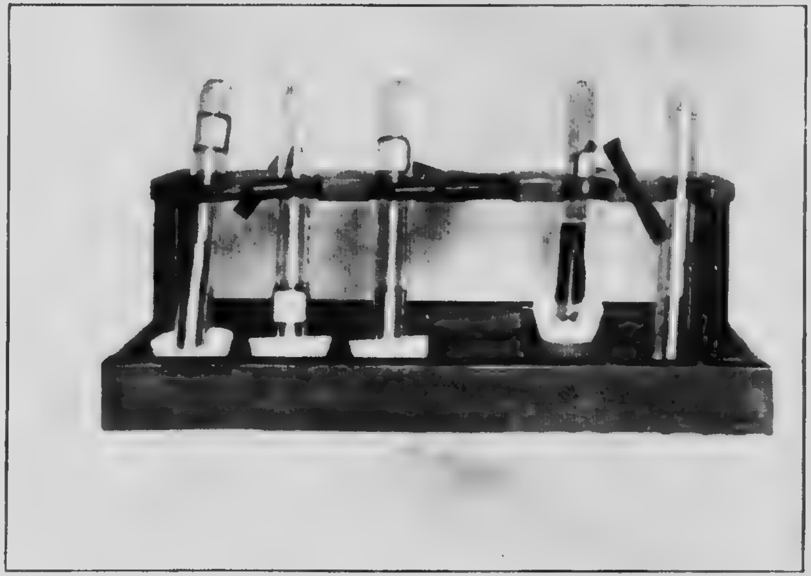
The reagents, etc., employed were as follows: (1) Caustic potash: 1 part by weight dissolved in 2 parts of water. (2) Pyrogallol: about 2 c.c. of a solution, made by dissolving 1 part by weight of the salt in 4 parts of water, were introduced into the laboratory vessel, and then four times as much of the above caustic potash solution also introduced; the pyrogallol keeps better acid so that it was only mixed with alkali when actually required; an excess of potash is added to prevent the pyrogallol evolving carbon monoxide, but even so a gas should never be left more than ten minutes over this reagent. (3) Bromine: a solution of bromine in 10 per cent potassium bromide was employed; for gases containing only small quantities of unsaturated hydrocarbons a saturated water solution to which potassium bromide was afterwards added was found to be sufficiently strong. As this reagent attacks the mercury slightly, the gas was never left more than five minutes over it, the vessel was rinsed out afterwards, first with caustic potash solution and then with 5 per cent sulphuric acid, and the gas was brought back into the laboratory vessel and treated with caustic potash to remove bromine vapour before it was remeasured in the measuring vessel. (4) Cuprous chloride: the gas was treated twice with ammoniacal cuprous chloride, prepared as described under the Randall and Barnhart apparatus. An ammoniacal solution of cuprous chloride, with a negligible vapour tension of ammonia, can also be prepared by suspending 75 grams of cuprous chloride in a solution of 15 grams of ammonium chloride in 300 c.c. of water, ammonia gas is then passed into the solution (kept out of contact with the air) until, after shaking the bottle the solution smells of ammonia when the cork is released; an hour or more will be required to saturate, excess should be avoided; 10 to 20 grams more of cuprous chloride are then added, the solution well shaken, and stored in a well stoppered bottle.

The whole of the gas left, after treating with the above reagents, was used for the explosion, it was mixed with excess of oxygen and the volume measured, about 4 c.c. electrolytic gas was added if necessary, the gas passed into the explosion tube, **E**, fired by a spark from an induction coil, returned to the measuring tube, remeasured, treated with potash in the laboratory vessel, and again remeasured; the calculations were made as already described. The rule as to the quantity of oxygen (or air) to be added for the explosion was that employed in Dr. Bone's laboratory—add oxygen sufficient to make the explosive mixture or *knallgas* (*i.e.* $CH_4 + 2O_2$ and $2H_2 + O_2$), and excess oxygen (or air) as diluent of at least twice the volume of the knallgas. Thus if 100 mm. of gas are taken for the explosion, of which probably 30 mm. at most are burnable; if the latter is chiefly hydrogen, 15 mm. of oxygen are required for its complete combustion, so that the quantity of knallgas would be 45 mm., it is, therefore, necessary, to take at least 15 + (2×45), that is 105 mm. of oxygen; or in other words the 100 mm. of gas should be made to at least 205 mm. with oxygen. This is the lowest limit, greater dilution is an advantage; with less dilution oxides of nitrogen and nitric acid are formed and some oxygen disappears, giving too great a contraction.

Oxygen was stored in a bottle over water, the gas was delivered through a suitable delivery tube into the laboratory vessel. Electrolytic gas was stored in test-tubes over mercury in a rack such as already described. Stopcocks were kept lubricated with a solution of rubber in vaseline, prepared by gently heating together 20 parts of pure rubber, 10 of vaseline, and 1 of paraffin wax; the heat was maintained and the mixture stirred until the rubber was completely dissolved.

The following example illustrates the method of recording an analysis made with the Bone and Wheeler apparatus:—

Plate LX.



Rack for holding and storing gas samples.

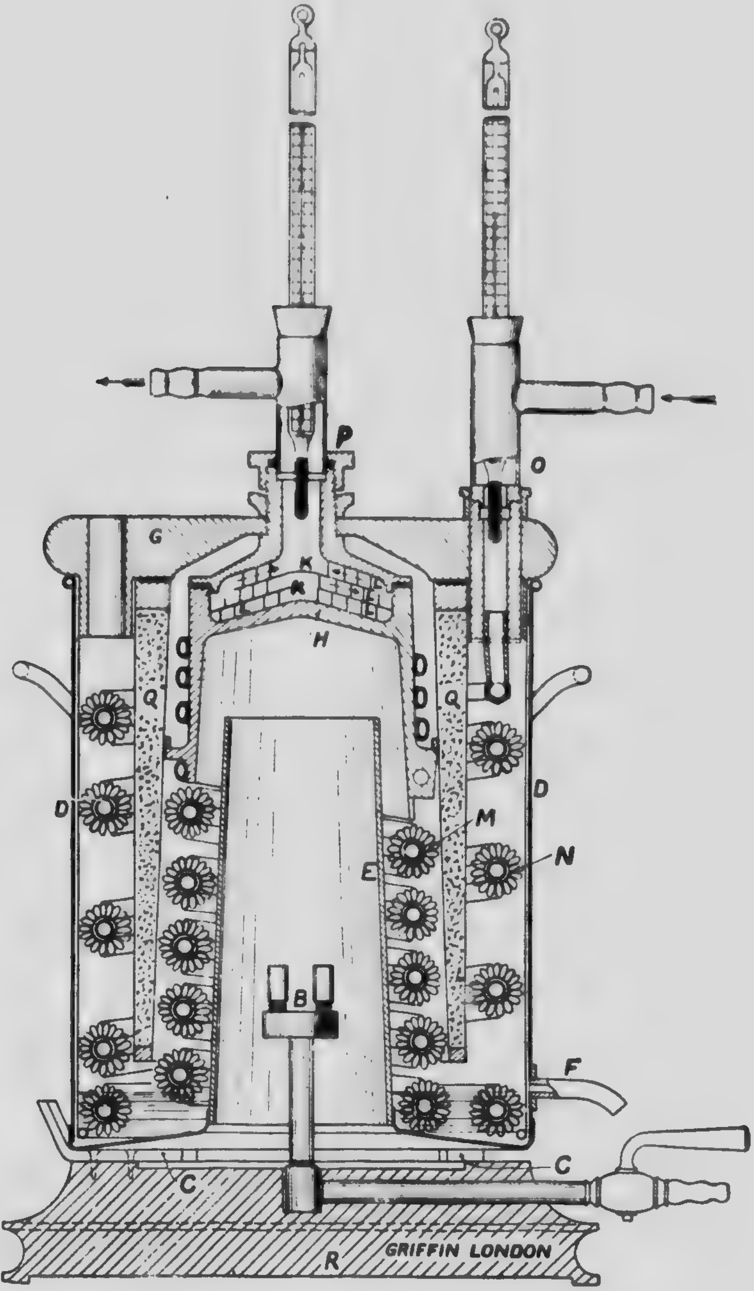


Fig. 55. Vertical section of Boys' gas calorimeter.

TABLE XLVII.

Analysis of Producer Gas With Bone and Wheeler Apparatus.

Vacuum reading	0.0 mm.			
Initial reading	120.5			
Gas taken	120.5			
After potash	109.4	Decrease 11.1 mm.	Carbon dioxide	9.2
After pyro.	108.7	0.7	Oxygen	0.6
After bromine	108.5	0.2	Ethylene	0.2
After cuprous chloride	92.0	16.5	Carbon monoxide	13.7
After adding oxygen	[illegible]			
After adding electrolytic gas	[illegible]			
After explosion	54.6	30.4		
After potash	50.5	4.1	Methane	3.4
Decrease due to hydrogen	30.4	[illegible] 4.1 [illegible]	[illegible]	
	21.[illegible]	14.6	Hydrogen	12.1
By difference			Nitrogen	60.8
				100.0

CALORIFIC VALUE OF GASEOUS FUELS

The calorimeter used for determining the calorific value of producer gas was one devised by Prof. C. V. Boys, and described by him in the Roy. Soc. Proc. 1906, 77A, p. 122; (also Jour. Soc. Chem. Indust., March 15, 1906, p. 231).

The usual method of gas calorimetry is employed, a jet of the gas is burnt in the calorimeter, and the heat of the combustion is absorbed by a current of water which flows through the instrument. The rate of flow of gas is determined by passing it through a gas meter, the rise in temperature of the water is determined by means of thermometers placed in the water at the points of entry and exit, and the rate of flow of the water is determined by collecting it in a measuring vessel: from these data the calorific value of the gas can be calculated.

The Boys gas calorimeter was designed to provide ample space for the circulation of the stream of burnt gases so that they pass slowly and freely through the instrument, and are thus effectively exposed to the cooling surfaces. The water content of the instrument has, on the other hand, been reduced to the smallest quantity; so that the outflowing water attains its ultimate temperature very quickly after the gas is lighted, and any variation in the temperature of the inflowing water is soon followed by a corresponding variation in the outflowing water. The whole of the circulating water takes continuously the same course, being debarred from any [illegible] [illegible], and thus unequal heating and the attendant irregularity of the temperature at the outflow are avoided. The small content of water becomes adequate to abstract the whole of the heat from the slowly travelling stream of gases mainly by reason of its flow through a pipe of small diameter, the heat-collecting power of which is greatly increased by attached wires.

The following description of the apparatus is taken from the Notification of the Metropolitan Gas Referees (London, Eng., for 1906).

The calorimeter is shown in vertical section in Fig. 55. It consists of three separate parts: (1) The base, R, carrying a pair of burners, B, (for producer gas these burners were replaced by a single, plain-tube burner) and a regulating tap. The upper surface of the base is covered with a bright metal plate on which are three centering and lifting blocks, **C**. The blocks are so placed as to carry (2) the vessel, **D**, which is provided with a central chimney of copper **E**, and an outlet, **F**, for condensed water. Resting upon the rim of the vessel, **D**, are (3) the essential parts of the calorimeter attached to the lid, **G**. Beginning at the centre where the outflow is situated, there is a brass box which acts as a temperature equalizing chamber for the outlet water. Two dished plates of thin brass, **K**, **K**, are held in position by three scrolls of thin brass, **L**,**L**,**L**. The lower or pendant portion of the box is kept cool by water circulating through a tube which is sweated on to the outside of the bell. Connected to this tube at its lowest point by a union are six turns of copper pipe such as is used in a motor car radiator of the kind known as Clarksons. In this a helix of copper wire threaded with copper wire is wound round the tube and the whole is sweated together by immersion in a bath of melted solder. A second coil of pipe of similar construction, surrounding the first, is fastened to it at the lower end by a union. This terminates at the upper end in a block to which the inlet water box and thermometer holder are secured by a union as shown at **O**. An outlet water box, **P**, and thermometer holder are similarly secured above the equalizing chamber. The lowest turns of the two coils, **M**,**N**, are immersed in the water which in the first instance is put into the vessel **D**, but which is supplemented by water condensed from the burnt gases: the excess of water escapes from the overflow pipe **F**.

Between the outer and inner coils **N**.**M**. is placed a brattice, **Q**, made of thin sheet brass containing cork dust to act as a heat insulator. The brattice is carried by an internal flange which rests upon the lower edge of the casting, **H**. A cylindrical wall of thin sheet brass, a very little smaller than the vessel **D**, is secured to the lid, so that when the instrument is lifted out of the vessel the coils are protected from injury. The narrow air space between this and the vessel **D**, also serves to prevent interchange of heat between the calorimeter and the air of the room. The two thermometers for reading the water temperatures and a third for reading the temperature of the escaping gases are all near together and at the same level: the two former are divided on the Centigrade scale into tenths of a degree, and are provided with reading lenses and pointers which slide upon them; they were calibrated in the Physics Department of McGill University. The lid may be turned round into any position relatively to the gas inlet and condensed water drip that may be convenient for observation, and the inlet and outlet water boxes may themselves be turned so that their branch tubes point in any direction.

The accessories of the calorimeter consist of a gas pressure regulator, gas meter with opal dial 9″ diameter, divided into 100 parts, capacity $\frac{1}{12}$ cubic foot per revolution; a measuring vessel of 2300 cc capacity, a change-over funnel to deliver water to the sink or measuring vessel as desired; and an overflow funnel to deliver water to the calorimeter at a constant head.

Fig. 56 shows the general view of calorimeter and accessories, and Plate XLIX (Part VIII) shows the calorimeter as set up on a special bench in the

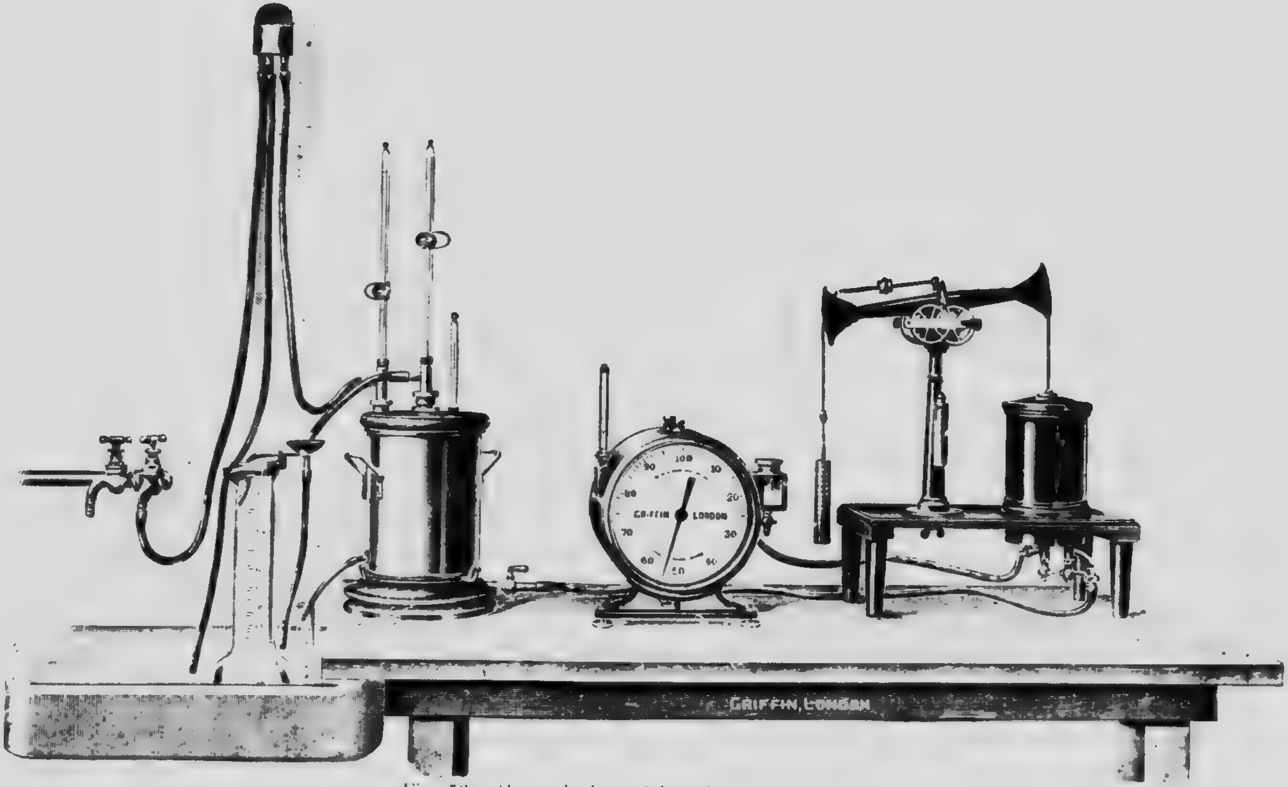


Fig. 56. General view of Boys' gas calorimeter.

gas producer house. Gas was supplied to the instrument from the gas main on the pressure side of the blower, it passed first through the pressure regulator, then the meter, and was finally burnt in the calorimeter—it should be noted that this order varies from that followed in testing city gas, in which case the gas passes through the meter first. The overflow funnel was fixed to the back of the bench at about 3 feet above the level of the instrument, the water flow thus regulated, was subsequently never changed; the gas was adjusted, when necessary, by the pressure regulator, so that when the burner was lit a rise of from 5° to 8°C. was produced in the temperature of the water during its passage through the calorimeter. The change-over funnel was placed on a rack over the measuring cylinder, and it was arranged that the outlet water from the calorimeter ran into the funnel and from thence, normally, into a waste pipe, but, that by moving the funnel it ran into the measuring vessel.

The burner of the calorimeter was lit at the beginning of a producer trial and kept burning throughout the trial, a determination was made as soon as the temperature became steady, and repeated at regular intervals during the trial; no determination was considered satisfactory in which there was any large variation in the inlet or outlet temperatures. The method was as follows: at a moment when the meter hand passed the zero mark the change-over funnel was moved to discharge into the empty measuring vessel, readings of the outlet temperature of the water were then taken once during each revolution of the meter until from 1600 to 1900 c.c. of water had been collected, the change-over funnel was then moved back when the meter hand again passed the zero. The inlet temperature was read at the beginning, middle, and end of the period; at the end the volume of water collected was noted, also the temperature of the gas in the meter, and the barometric pressure. As a rule ½ or ¾ of a cubic foot of gas (6 or 9 revolutions of the meter) were burned during an experiment.

If V = the volume of gas burned in cubic feet, as measured by the meter,

W = volume of water collected, in litres.
T_1 = the mean temperature of the inlet water, in degrees Centigrade.
T_2 " " " " " outlet " " " "
t = the temperature of the gas at the meter, in degrees Fahrenheit.
p = the vapour pressure of water at t°. F., in inches of mercury.
P = the barometric pressure, in inches of mercury.

then $V \times \frac{P-p}{30-0\cdot5} \times \frac{459+60}{459+t}$ is the volume of the gas burned, corrected to cubic feet of gas measured moist at 60°F. and 30″ of mercury pressure, the vapour of water at 60°F. is 0·5″ of mercury).

and

$$\frac{W \times (T_2-T_1) \times 3\cdot968}{V \times \frac{P-p}{30-0\cdot5} \times \frac{459+60}{459+t}} \quad \text{or} \quad \frac{W \times (T_2-T_1) \times (459+t) \times 0\cdot2255}{V \times (P-p)}$$

gives the calorific value of the gas in British Thermal Units per cubic foot of gas measured moist at 60°F. and under a pressure of 30″ of mercury.

(3·968 is the factor to convert kilograms calories into British Thermal Units).

The above is the gross calorific value: it was not thought worth while to collect the water from the burnt gas in order to determine the net calorific value.

The meter used was calibrated once a week by passing through it the air from a carboy of known capacity, and the volumes registered by the meter corrected when necessary. The necessity for this calibration was shown by the fact that a meter which had been in use some years gave readings nearly 11 per cent too low: the error being due to tar which had collected in the meter.

CALORIFIC VALUE CALCULATED FROM ANALYSIS OF GAS

By means of the following tables the gross and net calorific values of all producer gas samples analysed were calculated from the analysis, and expressed in B.T.U. per cubic foot of gas measured moist at 60°F. and under a pressure of 30″ of mercury. The data used in compiling these tables were as follows: -

1 (kilogram) calorie = 1000 calories = heat required to raise 1 kilogram of water from 15° to 16° C. = 3·968 B.T.U.

0°C. = 273° absolute. 60°F. = 15·5°C. = 288·5° absolute.

1 gram-molecule of a dry gas occupies 22·38 litres at 0°C. and 760 mm pressure.

Vapour pressure of water at 60°F. = 13 mm. of mercury.

30″ = 762 mm.

1 cubic foot = 28·31 litres.

Therefore, the factor required to convert calories per gram-molecule into B.T.U. per cubic foot of moist gas at 60°F. and 30″ pressure is: -

$$\frac{28{\cdot}31 \times 3{\cdot}968 \times 273 \times (762-13)}{22{\cdot}38 \times 288{\cdot}5 \times 760} = 4{\cdot}683$$

Gas.	Calorific value in cals. per gram-molecule		B.T.U. per cubic ft. at 60°F. and 30″
Ethylene (C_2H_4)	341·1	× 4·683	= 1597 gross.
	319·3	"	= 1495 net.
Carbon monoxide (CO)	68·2	"	= 319·4 gross and n
Methane (CH_4)	213·5	"	= 999·7 gross.
	191·7	"	= 897·6 net.
Hydrogen (H_2)	69·0	"	= 323·0 gross.
	58·1	"	= 272·0 net

The following example will make the use of the tables clear.

Analysis of Gas.		Calorific value from tables. Gross.	Net.
CO_2	9·8%		
C_2H_4	0·5	8·0	7·5
O_2	0·6		
CO	8·9	28·4	28·4
CH_4	3·6	36·0	32·3
H_2	10·4	33·6	28·3
N_2	66·2		
Total	100·0	106 B.T.U.	97 B.T.U.

TABLE XLVIII

Ethylene.

Gross or Higher Calorific Value in B.T.U. per cub. ft., moist, at 60°F. and 30″.

Percentage of Ethylene	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
0	0·0	1·6	3·2	4·8	6·4	8·0	9·6	11·2	12·8	14·4
1	16·0	17·6	19·2	20·8	22·4	24·0	25·6	27·2	28·8	30·3
2	31·9	33·5	35·1	36·7	38·3	39·9	41·5	43·1	44·7	46·3
3	47·9	49·5	51·1	52·7	54·3	55·9	57·5	59·1	60·7	62·3
4	63·9	65·5	67·1	68·7	70·3	71·9	73·5	75·1	76·7	78·3

Net or Lower Calorific Value in B.T.U. per cub. ft., moist, at 60°F. and 30″.

Percentage of Ethylene	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
0	0·0	1·5	3·0	4·5	6·0	7·5	9·0	10·5	12·0	13·5
1	15·0	16·4	17·9	19·4	20·9	22·4	23·9	25·4	26·9	28·4
2	29·9	31·4	32·9	34·4	35·9	37·4	38·9	40·4	41·9	43·4
3	44·9	46·4	47·8	49·3	50·8	52·3	53·8	55·3	56·8	58·3
4	59·8	61·3	62·8	64·3	65·8	67·3	68·8	70·3	71·8	73·3

TABLE XLIX

Carbon Monoxide.

Gross and Net Calorific Value in B.T.U. per cub. ft., moist, at 60°F. and 30″.

Percentage of Carbon Monoxide	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
5	16·0	16·3	16·6	16·9	17·3	17·6	17·9	18·2	18·5	18·8
6	19·2	19·5	19·8	20·1	20·4	20·8	21·1	21·4	21·7	22·0
7	22·4	22·7	23·0	23·3	23·6	24·0	24·3	24·6	24·9	25·2
8	25·5	25·9	26·2	26·5	26·8	27·1	27·5	27·8	28·1	28·4
9	28·7	29·1	29·4	29·7	30·0	30·3	30·7	31·0	31·3	31·6
10	31·9	32·3	32·6	32·9	33·2	33·5	33·9	34·2	34·5	34·8
11	35·1	35·5	35·8	36·1	36·4	36·7	37·1	37·4	37·7	38·0
12	38·3	38·7	39·0	39·3	39·6	39·9	40·3	40·6	40·9	41·2
13	41·5	41·8	42·2	42·5	42·8	43·1	43·4	43·8	44·1	44·5
14	44·7	45·0	45·4	45·7	46·0	46·3	46·6	47·0	47·3	47·6

TABLE XLIX (*Continued.*)

Gross and Net Calorific Value in B.T.U. per cub. ft., moist. at 60°F. and 30″.

Percentage of Carbon Monoxide	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
15	47·9	48·2	48·6	48·9	49·2	49·5	49·8	50·2	50·5	50·8
16	51·1	51·4	51·7	52·1	52·4	52·7	53·0	53·3	53·7	54·0
17	54·3	54·6	54·9	55·3	55·6	55·9	56·2	56·5	56·9	57·2
18	57·5	57·8	58·1	58·5	58·8	59·1	59·4	59·7	60·1	60·4
19	60·7	61·0	61·3	61·6	62·0	62·3	62·6	62·9	63·3	63·6
20	63·9	64·2	64·5	64·8	65·2	65·5	65·8	66·1	66·4	66·8
21	67·1	67·4	67·7	68·0	68·4	68·7	69·0	69·3	69·6	69·9
22	70·3	70·6	70·9	71·3	71·6	71·9	72·2	72·5	72·8	73·1
23	73·5	73·8	74·1	74·4	74·7	75·1	75·4	75·7	76·0	76·3
24	76·7	77·0	77·3	77·6	77·9	78·3	78·6	78·9	79·2	79·5
25	79·9	80·2	80·5	80·8	81·1	81·5	81·8	82·1	82·4	82·7
26	83·0	83·4	83·7	84·0	84·3	84·6	85·0	85·3	85·6	85·9
27	86·2	86·6	86·9	87·2	87·5	87·8	88·2	88·5	88·8	89·1

TABLE L.

Methane.

Gross or Higher Calorific Value in B.T.U. per cub. ft., moist. at 60°F. and 30″

Percentage of Methane	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0 9
0	0·0	1·0	2·0	3·0	4·0	5·0	6·0	7·0	8·0	[illegible]
1	10·0	11·0	12·0	13·0	14·0	15·0	16·0	17·0	18·0	19·0
2	20·0	21·0	22·0	23·0	24·0	25·0	26·0	27·0	28·0	29·0
3	30·0	31·0	32·0	33·0	34·0	35·0	36·0	37·0	38·0	[illegible]
4	40·0	41·0	42·0	43·0	44·0	45·0	46·0	47·0	48·0	49·0
5	50·0	51·0	52·0	53·0	54·0	55·0	56·0	57·0	58·0	[illegible]
6	60·0	61·0	62·0	63·0	64·0	65·0	66·0	67·0	68·0	69·0
7	70·0	71·0	72·0	73·0	74·0	75·0	76·0	77·0	78·0	[illegible]

TABLE L (*Continued*).

Net or Lower Calorific Value in B.T.U. per cub. ft., moist, at 60°F. and 30″

Percentage of Methane	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
0	0·0	0·9	1·8	2·7	3·6	4·5	5·4	6·3	7·2	8·1
1	9·0	9·9	10·8	11·7	12·6	13·5	14·4	15·3	16·2	17·1
2	18·0	18·9	19·8	20·6	21·5	22·4	23·3	24·2	25·1	26·0
3	26·9	27·8	28·7	29·6	30·5	31·4	32·3	33·2	34·1	35·0
4	35·9	36·8	37·7	38·6	39·5	40·4	41·3	42·2	43·1	44·0
5	44·9	45·8	46·7	47·6	48·5	49·4	50·3	51·2	52·1	53·0
6	53·9	54·8	55·7	56·6	57·5	58·4	59·3	60·1	61·0	61·9
7	62·8	63·7	64·6	65·5	66·4	67·3	68·2	69·1	70·0	70·9

TABLE LI

Hydrogen.

Gross or Higher Calorific Value in B.T.U. per cub. ft., moist, at 60°F. and 30″.

Percentage of Hydrogen	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
0	0·0	0·3	0·6	1·0	1·3	1·6	1·9	2·3	2·6	2·9
1	3·2	3·6	3·9	4·2	4·5	4·9	5·2	5·5	5·8	6·1
2	6·5	6·8	7·1	7·4	7·7	8·1	8·4	8·7	9·0	9·4
3	9·7	10·0	10·3	10·7	11·0	11·3	11·6	11·9	12·3	12·6
4	12·9	13·2	13·6	13·9	14·2	14·5	14·9	15·2	15·5	15·8
5	16·2	16·5	16·8	17·1	17·4	17·8	18·1	18·4	18·7	19·1
6	19·4	19·7	20·0	20·4	20·7	21·0	21·3	21·6	22·0	22·3
7	22·6	22·9	23·3	23·6	23·9	24·2	24·6	24·9	25·2	25·5
8	25·8	26·2	26·5	26·8	27·1	27·5	27·8	28·1	28·4	28·8
9	29·1	29·4	29·7	30·0	30·4	30·7	31·0	31·3	31·7	32·0
10	32·3	32·6	33·0	33·3	33·6	33·9	34·2	34·6	34·9	35·2
11	35·5	35·9	36·2	36·5	36·8	37·2	37·5	37·8	38·1	38·4
12	38·8	39·1	39·4	39·7	40·1	40·4	40·7	41·0	41·3	41·7
13	42·0	42·3	42·6	43·0	43·3	43·6	43·9	44·3	44·6	44·9
14	45·2	45·5	45·9	46·2	46·5	46·8	47·2	47·5	47·8	48·1
15	48·5	48·8	49·1	49·4	49·7	50·1	50·4	50·7	51·0	51·4
16	51·7	52·0	52·3	52·7	53·0	53·3	53·6	53·9	54·3	54·6
17	54·9	55·2	55·6	55·9	56·2	56·5	56·9	57·2	57·5	57·8
18	58·1	58·5	58·8	59·1	59·4	59·8	60·1	60·4	60·7	61·1
19	61·4	61·7	62·0	62·3	62·7	63·0	63·3	63·6	64·0	64·3
20	64·6	64·9	65·3	65·6	65·9	66·2	66·5	66·9	67·2	67·5

TABLE LI (*Continued*).

Net or Lower Calorific Value in B.T.U. per cub. ft., moist, at 60°F. and 30".

Percentage of Hydrogen	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
0	0·0	0·3	0·5	0·8	1·1	1·4	1·6	1·9	2·2	2·5
1	2·7	3·0	3·3	3·5	3·8	4·1	4·4	4·6	4·9	5·2
2	5·4	5·7	6·0	6·3	6·5	6·8	7·1	7·3	7·6	7·9
3	8·2	8·4	8·7	9·0	9·3	9·5	9·8	10·1	10·3	10·6
4	10·9	11·2	11·4	11·7	12·0	12·2	12·5	12·8	13·1	13·3
5	13·6	13·9	14·1	14·4	14·7	15·0	15·2	15·5	15·8	16·0
6	16·3	16·6	16·9	17·1	17·4	17·7	18·0	18·2	18·5	18·8
7	19·0	19·3	19·6	19·9	20·1	20·4	20·7	20·9	21·2	21·5
8	21·8	22·0	22·3	22·6	22·9	23·1	23·4	23·7	23·9	24·2
9	24·5	24·8	25·0	25·3	25·6	25·8	26·1	26·4	26·7	26·9
10	27·2	27·5	27·7	28·0	28·3	28·6	28·8	29·1	29·4	29·6
11	29·9	30·2	30·5	30·7	31·0	31·3	31·6	31·8	32·1	32·4
12	32·6	32·9	33·2	33·5	33·7	34·0	34·3	34·5	34·8	35·1
13	35·4	35·6	35·9	36·2	36·5	36·7	37·0	37·3	37·5	37·8
14	38·1	38·4	38·6	38·9	39·2	39·4	39·7	40·0	40·3	40·5
15	40·8	41·1	41·3	41·6	41·9	42·2	42·4	42·7	43·0	43·2
16	43·5	43·8	44·1	44·3	44·6	44·9	45·2	45·4	45·7	46·0
17	46·2	46·5	46·8	47·1	47·3	47·6	47·9	48·1	48·4	48·7
18	49·0	49·2	49·5	49·8	50·1	50·3	50·6	50·9	51·1	51·4
19	51·7	52·0	52·2	52·5	52·8	53·0	53·3	53·6	53·9	54·1
20	54·4	54·7	54·9	55·2	55·5	55·8	56·0	56·3	56·6	56·8

MISCELLANEOUS DETERMINATIONS

Specific Gravity of Coal—Typical pieces of coal of about 3 grams weight each, were taken, suspended by fine thread and weighed in air; they were then boiled in distilled water for from one-half to three-quarters of an hour, in order to remove the air from the pores, and then were cooled under reduced pressure, which removed any air still left in the coal, and the coal was finally weighed suspended in the water. The first weight of the coal divided by the difference between the first and the last weights gives the specific gravity of the piece of coal taken. This determination was not included in the regular tests made, as the heavy solution tests, described in Vol. I, Part V, gave similar but fuller and more valuable information.

Soluble Matter in Coal.—A sample of coal was treated with water with a view, chiefly, to determine whether any of the nitrogen compounds of the coal were soluble in water. The coal chosen for the experiment, No. 2010, contained 1·7 per cent nitrogen, 5·2 per cent sulphur, and 16·9 per cent ash. A tall cylinder was taken, and the shorter limb of a siphon tube introduced into it and connected at the end to an inverted funnel resting on the bottom of the cylinder. One kilogram of the coal, crushed to ¼" size, was put into the cylinder which was then filled with distilled water; the water was siphoned off at the rate of about half a litre a day; coal was prevented from entering the siphon tube by the inverted funnel, fresh water was added from time to time to replace that removed. The dissolved matter was found to consist almost entirely of iron salts, presumably formed by the slow oxidation of the iron pyrites in the coal, as these salts came over in larger quantities when the siphon was re-started after the cylinder had been allowed to run dry, and the moist coal thus brought into contact with the air. As after even four or five days extraction there did not appear to be any reduction in the material going into solution, the extraction was stopped, the solution was evaporated to dryness, and 13·1 grams of solid matter were thus obtained. This was found to contain only 0·18 per cent of nitrogen in the form of ammonium salts—corresponding to 0·0023 per cent in the coal—no albuminoid nitrogen and no nitrates.

Soluble Matter in Water.—A litre of the Montreal water, as used in the washing trials, etc., was filtered and then evaporated to dryness in a platinum basin over a water bath; the residue left, dried at 105°C., weighed 0·0984 grams; after it had been ignited in a muffle it weighed 0·0701 grams. These two weights correspond to 9·84 and 7·01 parts per hundred thousand respectively.

Hydrogen Sulphide and Sulphur Dioxide in Producer Gas.—These were first determined by the method described by J. C. Thomlinson in the "Chemical News" for Feb. 21, 1908. The gas was aspirated very slowly through a small bottle containing 25 c.c. of a water solution of iodine and of sodium carbonate, $\frac{1}{50}$ normal both as regards the iodine and the sodium carbonate (prepared by adding 50 c.c. of a decinormal solution of iodine in potassium iodide solution, to an equal volume of decinormal sodium carbonate solution, and diluting the mixture to 250 *c.c.*). The gas was stopped as soon as the iodine was decolourized; the volume of gas drawn through was determined by measuring the water run out of the aspirator bottle; and any sulphuric acid formed in the small bottle was determined by titration with standard alkali; from these data the percentages of hydrogen sulphide and sulphur dioxide present in the gas were calculated. The reactions involved are show by the following equations.

$$Na_2CO_3 + 2I + H_2S = 2NaI + CO_2 + H_2O + S$$
$$Na_2CO_3 + 2I + SO_2 + H_2O = 2NaI + CO_2 + H_2SO_4$$

As no sulphur dioxide was found in the first few samples, which were test by this method, a simpler method was substituted later to determine th hydrogen sulphide only; in this method two litres of the gas were aspirate through a solution of caustic soda, the solution was just acidified with hydr chloric acid, and the hydrogen sulphide present at once titrated with fiftieth normal iodine solution, with the addition of a little starch solution as indicato

This determination was only made for a few producer trials. Two tria were selected in which the coal being tested contained a high percentage sulphur, and a third with coal containing a medium percentage. The result obtained are as follows: gas from coal No. 10 (5·4 per cent sulphur) con tained, as the mean of three determinations, 0·22 per cent of hydrogen su phide; gas from coal No. 11 (5·8 per cent sulphur) contained, mean of te determinations, 0·40 per cent of hydrogen sulphide; and gas from coal N 36 (2·4 per cent sulphur) contained, mean of five determinations, 0·22 p cent by volume of hydrogen sulphide gas.

EXPERIMENTS ON THE FUSIBILITY OF ASHES.

Some experiments were made to find out whether it was possible to fo tell the trouble a coal would give in a boiler or producer, on account of for tion of clinker, by a determination in the laboratory of the fusibility of its

The determination of the fusibility of the ash was found to involve con siderable difficulties, largely occasioned by the fact that ash has no definite melting point, but appears to get gradually softer as the temperature In the method first employed, cones of ash were made, and these were he in a crucible inside a furnace, and the temperature noted at which the toppled over or gave other visible signs of fusion; the temperature wa corded by means of a pyrometer consisting of a platinum, platinum-ir thermocouple, the hot junction being placed almost in contact with the

The ash was prepared by burning the finely powdered coal in a m furnace and was, therefore, itself pulverulent. All attempts to make cones in a conical mould failed, so they had to be made by hand, a molasses diluted with water being used as a binding material. The cones first dried in an oven, and then given a preliminary gentle roasting furnace before being used. Each cone was placed on some neutral fractory material (such as chrome iron ore) in the bottom of the crucible, and the crucible was heated in a gas fired furnace in which the flames circled around it. When the crucible became white hot, it proved very difficult to observe the cone, even with blue glasses, unless it was either hotter or colder than the crucible, when it was silhouetted as a light or a dark object against the latter and could be easily watched, but, in such cases, the pyrometer readings could not then be relied upon to give the true temperature of the cone. The lack of uniformity of the handmade cones caused irregularity in the observed temperatures of fusion; a thicker or denser cone required a higher temperature than a thinner or lighter one before bending over, or collapsing. It was also shown that whereas one ash might soften at a low temperature and hardly show any further change with a considerable rise in temperature, another ash might not begin to soften until a high temperature and then might go quite liquid with only a slight further rise. It was, therefore, not only difficult to get consistent results by this method, but also the information obtained by it was too incomplete to be of much value.

In the second method several cylinders of ash were made in a briquetting press from each sample, and these were separately heated up to a definite temperature, one being heated to 1200°C., another to 1300°C., a third to 1400 C., and a fourth to 1500°C.; the temperatures were determined by means of a Morse optical pyrometer, and the effect on the ash cylinders was noted after they had been withdrawn from the oven. A simple form of press was used to make the cylinders, which were ⅜″ in diameter, about 1″ long, and with a slightly pointed top. A powerful mechanic's vice was used to apply pressure; the ash was just moistened with molasses and water to cause it to bind. The cylinders were mounted on small infusible base plates made of chrome iron ore, moulded damp after the addition of about 10 per cent of fireclay; three or four cylinders from different samples were mounted on each plate. These cylinders were heated on their plate on the bottom of a gas-heated furnace (designed by Dr. A. Stansfield), in which the air blast is preheated, and in which a very high and uniform temperature can be obtained; they were covered by an inverted graphite crucible with an opening cut in the side, through which the temperature could be observed with the optical pyrometer. In this method it was not necessary to watch the behaviour of the cylinders in the furnace, and the temperature of either a cylinder or the crucible could be determined by the optical pyrometer, in case they differed.

This method was not developed until after all the boiler and producer trials had been completed, and it was not thought worth while to carry out many tests; but seven sets of cylinders were heated after the method had been fully developed. The results are shown in Plates LXI and LXII. A was heated to 1200° C., B and E to 1300° C., C and F to 1400° C., J to 1500° C., and D to 1530° C. The tests showed that in the three cases tried, the ash from a washed coal was less fusible than the ash from the corresponding unwashed coal. The results are interesting, but it is difficult to see much connexion between them and the following data taken from the report of the boiler trials made on these coals; but the apparent discrepancies are possibly caused by variations in the temperature of the boiler fire.

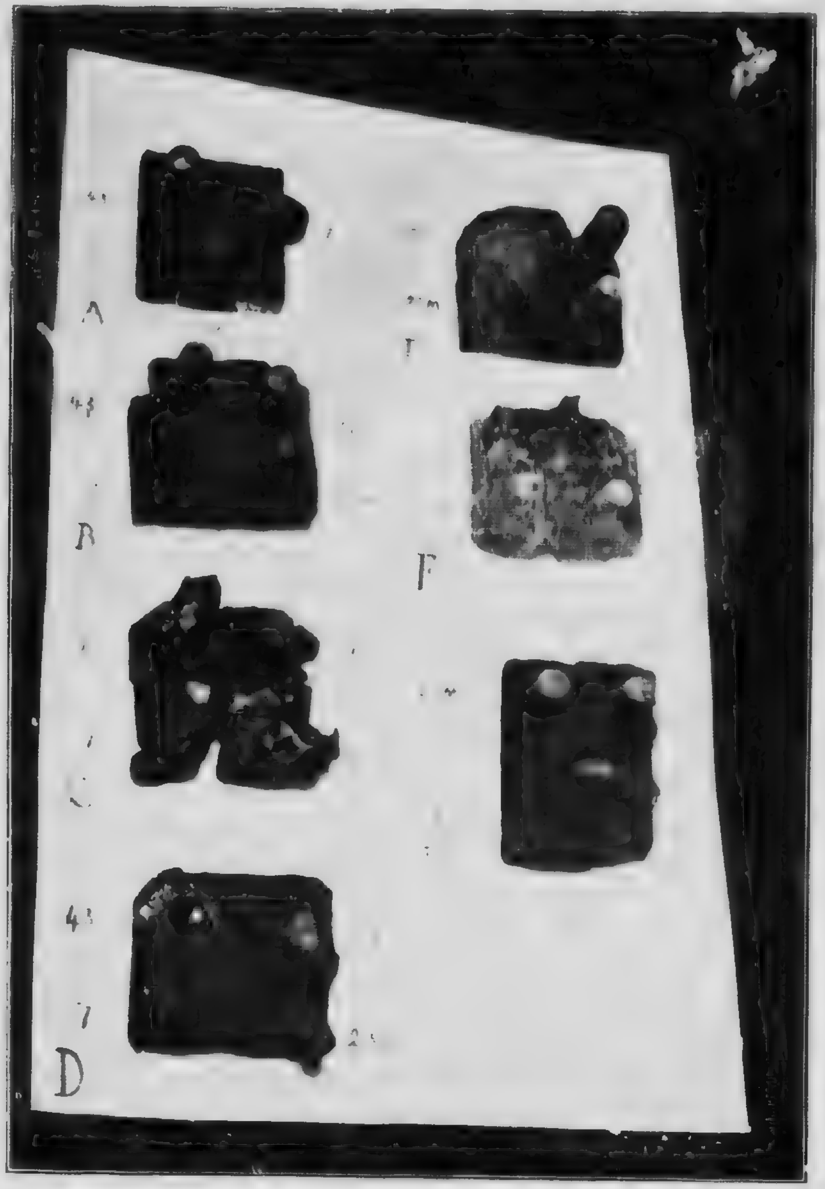
Coal 7 Clinker thin, vitreous and adherent
" 23 M Clinker very soft and easily removed, coal very suitable for shaking grate.
" 223 M (Coal 23M after washing) -Like 23 M
" 25 - Clinker hard: shaking grate could be used with steam
" 225 - (Coal 25 after washing) Hard layer of clinker sticking to bars until steam was put on: shaking grate might be used with steam.
" 36 - Bluish plastic clinker easily removed
" 236 - (Coal 36 after washing). Clinker troublesome until steam used.
" 13 - Clinker viscous, conditions improved with steam: shaking grate could be used with steam

DISCUSSION OF METHODS OF WORK

The prevention of moisture change in coal during sampling, grinding, and storage; the determination of water; and the effect of water on other analy are difficult problems of coal analysis. These problems were very careful considered before the methods employed were adopted, and most of the departures from more usual methods were made to lessen danger of erro through moisture.

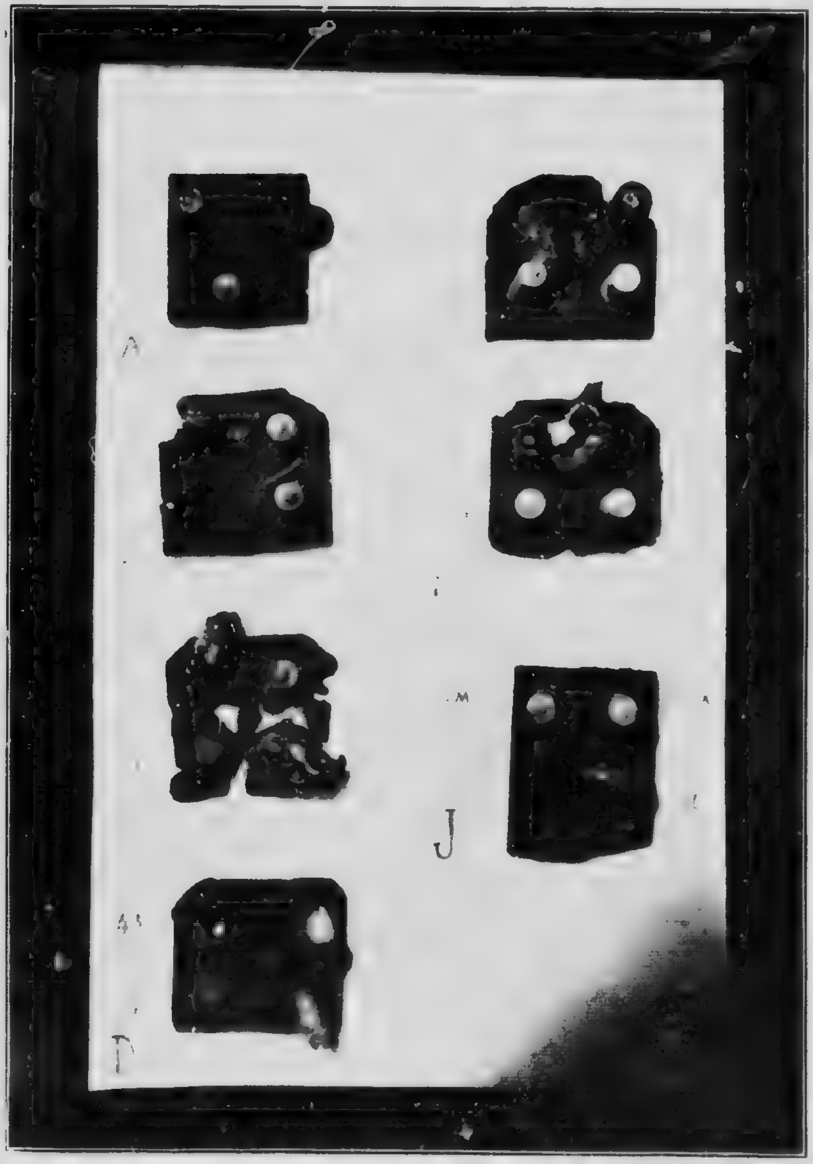
During the last four years, that is to say since the present investigation was begun, a number of papers have been published on the weathering of coal and allied problems, which show that coal samples undergo considerable oxidation when dried at 105° C., and also during storage at ordinary temperatures; these facts were known before, but the recent work has strongly emphasized the importance of bearing them in mind in all considerations of methods of analysis. It is now apparent that the laboratory work of the investigation would have been less open to criticism in this respect, if the analyses had been made on air dried samples, or if the coal had been dried in an atmosphere of nitrogen or other inert gas instead of in heated air. Coal analyses are, however, most conveniently useful when reported on the dry coal and there is a distinct advantage in making the analyses in the way they are to be reported rather than in analysing moist samples and correcting for the moisture contained. The error caused by oxidation of the coal during drying is, fortunately, rarely if ever serious, except possibly with lignites, and unfortunately the pressure of imperative work prevented any attempt being made to determine the exact extent of the change they undergo in this way. The oxidation of the ground sample after drying might have been prevented by making a complete analysis of each sample as soon as it was prepared, but, as has already been stated, this would have been quite impossible without a far larger staff and equipment.

In order that the analyses made should represent the coal as mined, it would have been necessary to sample the coal underground, ship in a hermetically sealed container to the laboratory, and make the complete analyses



Ash cylinders after heating, viewed at an inclination.

Plate LXII.



The cylinders after heating. Viewed from above.

soon as this container was received; such analyses would however, have been of doubtful value, as they would not represent the product of the mine as it reaches the consumer.

The whole subject of coal analysis is so beset with difficulties that it is almost impossible to avoid one difficulty without encountering another

A committee of the International Congress of Applied Chemistry is at present considering the question of moisture in fuels (and ores), and it is to be hoped that they will be able to suggest, in their report to the meeting in New York in 1912, some method of analysis which will meet with general international adoption. In view of this it is now only necessary to discuss the advantages and disadvantages of some of the methods actually employed not to suggest or recommend methods for Canadian adoption. other methods have been sufficiently discussed in describing them.

The method employed for obtaining a sample from the main consignment of coal was very thorough, and guarded against the greatest difficulty in sampling which lies in ensuring that a correct proportion of fines and of lump go into each portion every time the sample is subdivided by shovel or by riffle. In cases where a coal seam contains two portions, one of which is much stronger than the other, the fines and the lumps of coal sometimes differ considerably in composition and a true sample is hard to obtain. One coal in the series showed this characteristic to an exceptional degree, the different subsidiary samples checking badly (as to ash content) amongst themselves and with the main sample; several fresh samples of this coal were prepared and the one finally chosen for analysis was that in which the ash content came nearest to being the mean of that of the other samples.

It was necessary to decide, at the beginning of the investigation, between the relative merits of snap samples and average samples for flue gas and producer gas; that is between samples taken at a particular time and samples taken to represent the average gas produced during a given interval of time, such as one hour. It was decided that the snap sample was the better. In boiler trials, the flue gas analysis serves to indicate, both to those in charge of the trial during its operation and also to those who study the records afterwards, the way in which the stoking was carried out; for both these purposes the snap sample, taken when the boiler was in normal operation and not whilst firing or slicing was going on, gives the fullest information. The average sample is only better as giving information as to the total heat wasted up the chimney; of these uses, that of assisting in the correct stoking during the course of the trial was regarded as the most important, and the snap sample was, therefore, adopted; similar reasons led to the adoption of snap samples for producer trials also.

The system of air drying employed appeared on the whole to be very satisfactory: the length of time taken to dry a sample was a disadvantage in that the coal was doubtless slowly oxidizing during this time, but, as the air dried samples were not afterwards employed for the regular analyses of the coal this did not seriously matter. In this and all other moisture determinations a slightly more accurate result could possibly have been obtained by weighing the water driven off from the coal, rather than by noting the loss weight of the sample, which latter is affected by any loss due to escapin gases, and by any gain due to absorption of oxygen; but this metho while practicable, would have involved an unjustifiable amount of work.

The ball mill was chosen to grind coal samples because it enables comp. atively large samples to be finely ground and thoroughly mixed without a appreciable change in moisture. A screen analysis of a coal ground for th hours in the mill showed that only 0·05 per cent stayed on a 100 mesh scre and 1·25 per cent on a 200 mesh screen: this very fine grinding is an adva age in that any impurities will be very thoroughly disseminated through the whole sample, moisture can be quickly and completely removed, determinations such as that of sulphur can be more satisfactorily made fine samples than on coarse; it is a disadvantage in that more surface of coal is exposed and, therefore, oxidation can proceed more rapidly and fart

The advantages of the use of small sample tubes for the final sample h been mentioned: that their contents were liable to deterioration, in of their being closed with waxed corks and stored in stoppered bottles, shown in the following way. Briquettes sufficient for two determinati of calorific value were usually made soon after the sample had been prepa if for any reason these were not sufficient and fresh briquettes were made a later date for extra determinations, the fresh briquettes usually gave lower calorific value than the old ones, showing that the coal stored a impalpable powder in a tube, deteriorated more rapidly (by oxidation fro the air contained in the tube) than the same coal stored in the form strongly compressed briquettes. The difference found varied with the coal being highest with the lignites, but after two or three months storage usually amounted to about 50 calories per gram. The oxidation of the co samples is also shown by comparison of the analyses given of the re samples and those obtained later for coking tests; the latter samples analysed shortly after being received, and in nearly every case the pe centage of oxygen found in them was less than in the corresponding re samples, the completion of the analysis of which was more delayed

It is well known that, in the determination of volatile matter in the size of the crucible employed, temperature of the flame used, etc affect the result obtained. The results obtained in this investigation methods already described are probably not only consistent amongst selves, but also in close agreement with the results that would be obtain other chemists in general practice. As it is generally considered nec to determine volatile matter on air dry rather than on dry co determination was made on nearly all regular samples in both way the 73 samples tested in both ways (lignites excluded), 37 gave the result with dry coal and the average difference was 0·74 per cent, wh gave the higher result with air dried coal with an average difference per cent.

In the determination of ash it was found that different method lightly different results: ash was seldom determined in any sample

three methods employed, but the following comparisons have been calculated from the determinations made in two or more ways:—

TABLE LII

Comparative Ash Determinations.

	Coal burned in muffle.	Coal burned over burner.	Coal burned in oxygen in combustion furnace.
Mean of 11 determinations	14·45%	14·56%	14·59%
Mean of 80 "	10·72		11·09
Mean of 3 "		5·51	5·66

It has already been shown that the ash left after the oxidation of coal is not the same as the original mineral impurity in the coal; the original impurities in the coal are changed in different ways according to the rapidity of oxidation and the temperature to which they are subjected. Thus, for example, sulphur present in pyrites in the coal may be partially oxidized to sulphur dioxide and escape as such, or may be more completely oxidized to sulphuric anhydride and remain in the ash as a sulphate of calcium or other metal. Carbonates may be more or less completely decomposed, with the evolution of carbon dioxide, according to the temperature employed. The muffle furnace gives a higher temperature and less energetic oxidation than is usually the case in a combustion furnace—two conditions which lead to a lower result for the ash. W. Pollard has shown[1] that in a case where the percentage of ash found in a combustion tube was higher than in a muffle, the percentage of sulphur in the ash was correspondingly higher. It is worth noting that, in the seventy boiler trials carried out, the ash and clinker left behind at the end of a trial, after deducting the combustible matter present, weighed on the average over 25 per cent less than the weight of ash put into the boiler as calculated from the analysis of the coal; doubtless much of this loss is due to ash carried over into the flues and up the smoke stack, but it seems probable that some of the discrepancy is due to the difference in conditions between the boiler furnace and the muffle furnace.

Some of the errors in coal analyses are due rather to certain constituents of the coal, than to the particular methods employed for analysis; the following are referred to by Dr. Pollard in the article already mentioned.

When coal contains carbonates—usually of calcium and magnesium—not only does it affect the ash as stated before, but, in the determination of volatile matter carbon dioxide is evolved, and is thus reckoned as volatile matter rather than as ash, as it should be if ash is considered to be the original mineral matter in the coal; the escaping carbon dioxide may also be partially reduced at the expense of the carbon present—$CO_2 + C = 2CO$—the percentage of fixed carbon found being thus too low. In the ultimate analysis the percentage of ash found will be too low, and the carbon and oxygen too high. If, however, ash is considered to be the residue left after complete oxidation, no error is caused, except that in differen determinations the carbonate will be decomposed to a greater or less exten according to the temperature employed, so that duplicates will not agree.

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[1] See Chapter on "Accuracy of Coal Analysis" by W. Pollard, in "The Coals of South Wales," a memoir of the Geological Survey of England and Wales, 1908.

Ferrous minerals in the coal become oxidized to the ferric condition wh burnt, so that so far as they are concerned the ash found by analysis is great than in the original coal, and the oxygen, which is found by difference, i therefore, lower.

Pyrites in the coal are also oxidized when the coal is burned, the ir being left as ferric oxide; for every 240 parts by weight of iron pyrites in the original coal, 160 parts of ferric oxide will be weighed in the ash, and 12 parts of sulphur in the sulphur determination; the result again is that th determined oxygen is less than in the original coal.

Coal may also contain as impurity, minerals containing water of co stitution not driven off by drying at 105°C. The hydrogen and oxygen of such water will appear in the results of the analysis as hydrogen and oxygen of the coal instead of in the ash.

Dr. Pollard summarizes the approximate errors considered by him, in the following table. "No great accuracy is claimed for these figures, they are only intended to show in what direction, and approximately to what extent, the composition of a coal may be affected." The figures given refe to the percentages of the constituents calculated to an ash and sulphur free coal

TABLE LIII

Summary of Approximate Errors in Coal Analyses.

	C %	H %	O %	N %	C/H Rat
Carbonates	−1·14	−0·07	+1·22	−0·01	+0·1
Ditto in extreme case	−4·4	−0·2	+4·7	−0·1	+0·8
Ferrous minerals in ash	+0·2	....	−0·2	....	+0·1
Pyrites	+0·85	+0·05	−0·90	+0·01	
Hydrous minerals	....	+0·1	....	....	−0·4
Maximum observed alteration in four Welsh coals after four years storage[1]	−1·39	0·21	+1·43	+0·17	+0·7

In conclusion it should be explained that the methods which were em ployed have been fully described and possible errors indicated in order that the following analyses can be judged upon their merits. It should be clearly understood that the majority of possible errors, whilst affect ing the absolute analysis of any coal to a limited extent, will have little or no effect upon the relative merits of the coals judged from the analyses. The coals were all analysed in the same way, except for trifling differences already mentioned, so that the analyses are consistent amongst themselves.

It also seems desirable to call attention to the fact that the inh difficulties and errors of any known method of coal analysis are such, that, although in the work of this investigation very great care was taken both in the choice of methods and in the carrying out of the work, yet it would be unscientific and would give a false idea of accuracy, to report analyses to one hundredths of one per cent, or calorific values to the single calorie. The very general and misleading custom among coal chemists of expressing results to the hundredth of one per cent, even in proximate analyses where the very units are doubtful, is only excusable, because it is the custom, and because those chemists, whose work is sufficiently careful to enable them to realize the unavoidable inaccuracies, do not care to appear to be making less careful analyses than others.

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[1] Two of these coals were bituminous, one was a steam coal, and the last was an cite. The maximum alteration occurred with the bituminous coals, the alteration w the steam coal was very slight and with the anthracite it was practically *nil*.

LIST OF COALS TESTED

SYDNEY COAL FIELD, CAPE BRETON CO., N.S.

50*	Gowrie seam, North Atlantic Collieries Ltd., Port Morien, N.S.
36	Dominion No. 7. Hub seam, Dominion Coal Co., Ltd., Glace Bay, N.S.
35	Dominion No. 9. Harbour seam, Dominion Coal Co., Ltd., Glace Bay, N.S.
35 SP	Dominion No. 5. Phalen seam, Dominion Coal Co., Ltd., Glace Bay, N.S.
38	Dominion No. 1. Phalen seam, Dominion Coal Co., Ltd., Glace Bay, N.S.
37	Dominion No. 10. Emery seam, Dominion Coal Co., Ltd., Glace Bay, N.S.
39	Dominion No. 12. Lingan seam, Dominion Coal Co., Ltd., Glace Bay, N.S.
13	No. 1 Colliery, Nova Scotia Steel and Coal Co., Ltd., Sydney Mines, N.S.
12	No. 3 Colliery, Nova Scotia Steel and Coal Co., Ltd., Sydney Mines, N.S.

INVERNESS COAL FIELD, INVERNESS CO., N.S.

14	Inverness Colliery, Inverness Railway and Coal Co., Inverness, N.S.
15	Port Hood Colliery, Richmond Railway Coal Co., Ltd., Port Hood, N.S.

PICTOU COAL FIELD, PICTOU COUNTY, N.S.

4	Six Foot seam, Vale Colliery, Acadia Coal Co., Ltd., New Glasgow, N.S.
17	Foord seam, Allan Shaft Colliery, Acadia Coal Co., Ltd., Stellarton, N.S.

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*The distinguishing numbers of the coal samples were arbitrarily assigned at the time, and have been retained for convenient reference. They have no other significance. J. B. P.

1 **Third seam, Albion Colliery, Acadia Coal Co., Ltd., Stellarton, N.S.**

2 Cage Pit seam, Albion Colliery, Acadia Coal Co., Ltd., Stellarton, N.S.

8 Main seam, Acadia Colliery, Acadia Coal Co., Ltd., Westvill N.S.

3 Main seam, Drummond Colliery, Intercolonial Coal Mining Co Ltd., Westville, N.S.

SPRINGHILL COAL FIELD, CUMBERLAND CO., N.S.

49 No. 1 Colliery, Cumberland Railway and Coal Co., Ltd., Springhi N.S.

5 No. 2 Colliery, Cumberland Railway and Coal Co., Ltd., Springh N.S.

6 No. 3 Colliery, Cumberland Railway and Coal Co., Ltd., Springh N.S.

JOGGINS-CHIGNECTO COAL FIELD, CUMBERLAND CO., N.S.

7 Chignecto Colliery, Maritime Coal, Railway, and Power Co., L Chignecto, N.S.

9 Minudie Colliery, Minudie Coal Co., Ltd., River Hebert, N.S.

10 Joggins Colliery, Canada Coals and Railway Co., Ltd., Joggi N.S.

GRAND LAKE COAL FIELD, QUEENS CO., N.B.

11 King's mine, G. H. King, Minto, N.B.

SOURIS COAL FIELD, SASK.

10 Western Dominion Collieries, Ltd., Taylorton, Sask

11 Eureka Coal and Brick Co., Ltd., Estevan, Sask

EDMONTON COAL FIELD, ALTA.

16 Strathcona Coal Co., Ltd., Strathcona, Alta.

12. Parkdale Coal Co., Ltd., Edmonton, Alta.

15 Standard Coal Co., Edmonton, Alta.

BELLY RIVER COAL FIELD, ALTA.

13 Canada-West Coal Co., Ltd., Taber, Alta.

14 Galt Colliery, Alberta Railway and Irrigation Co., Ltd., bridge, Alta.

17 Breckenridge and Lund Coal Co., Ltd., Lundbreck, Alta.

FRANK-BLAIRMORE COAL FIELD, ALTA.

18 Seven Foot seam (No. 1 Byron), Leitch Collieries, Ltd., Passburg, Alta

32 Hillcrest Colliery, Hillcrest Coal and Coke Co., Ltd., Hillcrest, Alta

33 Bellevue Colliery, No. 1 seam, West Canadian Collieries Co., Ltd., Bellevue, Alta

28 Lille Colliery, No. 1 seam, West Canadian Collieries Co., Ltd., Lille, Alta.

34 Denison Colliery, No. 2 seam, International Coal and Coke Co., Ltd., Coleman, Alta

34 SP Denison Colliery, No. 4 seam, International Coal and Coke Co., Ltd., Coleman, Alta.

CROWSNEST COAL FIELD, B.C.

31 No. 3 mine, Michel Colliery, Crowsnest Pass Coal Co., Ltd., Michel, B.C.

30 No. 7 mine, Michel Colliery, Crowsnest Pass Coal Co., Ltd., Michel, B.C.

29 No. 8 mine, Michel Colliery, Crowsnest Pass Coal Co., Ltd., Michel, B.C.

51 No. 2 seam south, Hosmer Mines, Ltd., Hosmer, B.C.

52 No. 6 seam south, Hosmer Mines, Ltd., Hosmer, B.C.

53 No. 8 seam south, Hosmer Mines, Ltd., Hosmer, B.C.

27 No. 2 mine, Coal Creek, Crowsnest Pass Coal Co., Ltd., Fernie, B.C.

26 No. 5 mine, Coal Creek, Crowsnest Pass Coal Co., Ltd., Fernie, B.C.

CASCADE COAL FIELD, ALTA.

25 No. 1 or Old mine, H. W. McNeil Co., Ltd., Canmore, Alta

23 Pea size, Bankhead Colliery, Bankhead Mines, Ltd., Bankhead, Alta.

23 SP Buckwheat size, Bankhead Colliery, Bankhead Mines, Ltd., Bankhead, Alta.

23 M Mixed, 23 and 23SP, Bankhead Colliery, Bankhead Mines, Ltd., Bankhead, Alta.

24 Briquettes from Bankhead Colliery, Bankhead Mines, Ltd., Bankhead, Alta.

SIMILKAMEEN COAL FIELD, B.C.

Ex. 1 No. 1 opening, Granite Creek, B.C.

Ex. 2 No. 2 opening, Granite Creek, B.C.

Ex. 3 No. 4 opening, Granite Creek, B.C.

NICOLA VALLEY COAL FIELD, B.C.

22 Jewel seam, No. 1 mine, Middlesboro Colliery Nicola Vall Coal and Coke Co., Ltd., Coutlee, B.C

22 SP Rat Hole seam, No. 2 mine, Middlesboro Colliery, Nicola Vall Coal and Coke Co., Ltd., Coutlee, B.C.

22 M Mixture of 22 and 22SP, Middlesboro Colliery, Nicola Vall Coal and Coke Co., Ltd., Coutlee, B.C

NANAIMO-COMOX COAL FIELD, VANCOUVER ISLAND, B.C

20 Wellington seam, Wellington Extension Colliery, Wellingto Colliery Co., Ltd., Extension, B.C

18 Upper seam, No. 1 mine, Western Fuel Co., Ltd., Nanaim B.C.

17 Lower seam, No. 1 mine, Western Fuel Co., Ltd., Nanaim B.C

21 Lower seam, No. 4 mine, Comox Colliery, Wellington Collie Co., Ltd., Cumberland, B.C.

21 SP Lower seam, No. 7 mine, Comox Colliery, Wellington Collie Co., Ltd., Cumberland, B.C.

21 M Mixture of Nos. 4 and 7 mines, Comox Colliery, Wellin Colliery Co., Ltd., Cumberland, B.C.

ALERT BAY COAL FIELD, VANCOUVER ISLAND, B.C.

Ex. 34 Suquash mine, Pacific Coast Coal Co., Alert bay, Van island, B.C

WHITEHORSE COAL FIELD, YUKON TERRITORY

Ex. 31 Upper seam, Tantalus mine, White Pass and Yukon Railwa Ltd., Yukon

Ex. 32 Middle seam, Tantalus mine, White Pass and Yukon Railway Ltd., Yukon

Ex. 33 Lower seam, Tantalus mine, White Pass and Yukon Railw Ltd., Yukon.

INDEX

PAGE

A

Acadia Coal Co., coals tested 42, 108
Air used for combustion in boiler test 14
Alberta Railway and Irrigation Co., Ltd., coal tested 45, 110
American Chemical Society, method of determining oxygen in coal 145
American Chemical Society, method of determining amount of fixed carbon and volatile matter. 134
Analysis of producer gas with Bone and Wheeler apparatus 161
Analysis of producer gas with Randall and Barnhart apparatus 161
Analytical methods and derived results. 131
Apparatus in chemical laboratory 131
Ash, determination of 178
" in coal 6
" samples, how obtained 126
" " how tested 136
Ashes, experiments on fusibility of 174
Atwater and Snell, use of bomb calorimeter 155

B

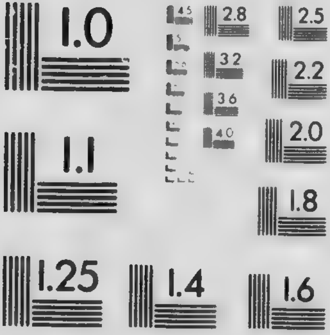
Babcock and Wilcox boiler used in test 15
Ball mill for grinding samples, advantages of 178
Bankhead Mines, Ltd., coals tested 48, 115
Beckmann thermometer 147
Belly River coal f[illegible] [illegible] tested 110
Boehmer, R. S. 122
Boiler and plant, description of that used in tests 15
Boiler tests, 3, 9
" " conditions governing 12
" " method of conducting 18
" " [illegible] 32
" " [illegible] 12
" " sources of error 9
Boilers, types and efficiency 3
Bone and Wheeler gas analysis apparatus 161
Boys, Prof. C. V., gas calorimeter 165
Briquettes for d[illegible] [illegible] 178
" from Bankhead coal tested. 48
" from coal samples 148
" used in Koerting gas producer 63
British Thermal Unit, definition 5

C

Calculations for boiler trial 27
Calorific tests, explanatory notes 152
" " method of recording readings and calculations of determinations 151
Calorific value ash free coal 155
Calorific value, calculated from analysis of coal 155
" " calculated from analysis of gas 168
" " gaseous fuels 165
" " solid fuels 146
Campbell, M. R., carbon-hydrogen classification of coal 156
Campbell, W. B. 122
Canada Coal and Railway Co., Ltd., coals tested 44
" West Coal Co., coal tested 45 110
Carbon and hydrogen in coal, how determined 136
" hydrogen ratio 156
Cascade coal field, coal tested 85, 115
Chemical laboratory work of 121
" tests, records how kept 129
Chlorine, effect of in coal 6
Clinkers, formation of 6, 59
Coal, air drying 130
" analysis, difficult problems of 176
" anthracites, Crowsnest and Alberta good results from 118
" bituminous, effect of in gas producer 62
" " Nicola Valley and Nanaimo coal fields 117
" " Springhill and Joggins field 109
" caking of 7
" calorific value calculated from analysis 155
" calorific value of ash free 155
" carbon hydrogen ratio 156
" composition of 32
" condition of when tested 33
" determination of volatile matter in [illegible]
" economic value of samples tested 35
" fuel ratio of 156
" lignites mixed special trial 112
" mechanical strength and hardness 7
" [illegible] 34
" [illegible] 173
" specific gravity of 173
" suitability of for steam generating 5
" treatment and behaviour of in fire 39
" trials of Georges Creek coal [illegible]
" value of different kinds for steam purposes 32
Coals, relative merit of gas producer work [illegible]
" remarks on as arranged geographically 40, 107
" tested, list of 181
" value of for gas producer work 102

MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No 2



APPLIED IMAGE Inc

PAGE

Coals, various, heat expenditure with . . . 118
Coke samples, how obtained 126
" tests for fixed carbon and volatile matter 134
Conway, E. J. 122
Crowsnest coal field, coals tested 47, 113
" Pass Coal Co., Ltd., coals tested 47, 113
" coals, special test 111
Cumberland Railway and Coal Co., coals tested . . 43

D

Diagram typical of boiler trial curve sheets 25
" typical of gas producer curve sheets . . 88
Dominion Calcium Light Co., oxygen supplied by 139
Dominion Coal Co., coals from tested 107
" " remarks on samples from . 40
Dowling, D. B., fuel ratio of coal 156
Drummond colliery, coal from tested 109
Durley, R. J., gas producer designed by . 74
" report on boiler tests 3
" report on gas producer tests. 55

E

Edmonton coal fields, coal from tested. 110
Efficiency of gas producers. 60
Elliott, P. H. 122
Eschka process for sulphur determination. . . 140
Explosion in gas producer plant, risk of slight 59

F

Fireman, importance of method of firing . 11
Flow sheet, treatment of main sample 123
Flue gas, relative merits of samples for tests 177
Frank-Blairmore coal field, coals tested . . 46, 112
Furnaces, and their adaptability. . 7

G

Gas analysis . . . 157
" producer efficiency 103
" tests, computation of fuel consumption 67
producer tests, details of . . . 82
" " " equipment of plant . . 72
" producer tests, estimating results . 69
" producer tests, methods of conducting and making measurements . 79

PAGE

Gas producer tests, methods of testing 66
" producer tests, remarks on results 102
" producer tests, report on 55
" " " typical example of curve diagrams . 88
" producer trial No. 32, detailed results 85
Gas producers used in tests 75
Gas samples, how obtained 12
Georges Creek coal, trials of 36
Grand Lake coal fields, coals tested 44, 10

H

H. W. McNeil Co., coals tested 48, 115
Hartley, H. 122
Heat expenditure with various coals 118
Hillcrest Coal and Coke Co., Ltd., coals tested 46
Hosmer Mines, Ltd., coals tested 47

I

Intercolonial Coal Mining Co., coals tested 42, 10
International Coal and Coke Co., Ltd., coals tested . 46, 11
Inverness coal field, tests of coal from . . 41, 10
" Railway and Coal Co., coals tested
" and Pictou coal fields, coals tested from

J

Joggins-Chignecto coal field, coals tested . . . .

K

King's mine, Minto, N.B., coals tested
Kjeldahl method of nitrogen determination
Koerting gas producer

L

Leitch Collieries, Ltd., coals tested 46
Lignite, moisture in
Lignites, excellent performance of
" fixed carbon and volatile matter in
" Saskatchewan and Alberta
Log of boiler trial No. 38
" " producer trial No. 32
Loomis-Pettibone gas producer system
Lord, Prof. N. W., method of testing for carbon and hydrogen

M

Mahler calorimeter . .
Maritime Coal, Railway and Power Co., coals tested
[illegible] W. B.
Minudie Coal Co., Ltd., coals tested
Mohan, R. T. .

PAGE
Moisture in coal, effect of 6
" " samples, how calculated 134
" " steam 13, 16
Mond process gas producer 65
Morrison, H. G. 122

N

Nanaimo coal field, coal tested 117
Nanaimo-Comox and Alert Bay coal fields, coal tested . 50
Nicola Valley Coal and Coke Co., coal tested . 19, 117
" " coal field, coal tested 19, 117
Nicolls, J. H. H. 122
Nitrogen, determination of 143
Nova Scotia Steel and Coal Co., coal from tested . 107
Nova Scotia Steel and Coal Co., remarks on samples from. 10

O

Orsat Muncke apparatus . 158
Oxygen, determination in coal 145

P

Pacific Coast Coal Co., Ltd., coals tested . . . 50
Parkdale Coal Co., coal tested . 45, 110
Peabody throttling calorimeter .. 16
Pictou coal field, tests of coal from 42, 108
Poisoning from producer gas, remedy for 60
Pollard, Dr. W., methods of ash determinations . 179, 180
Port Hood colliery, coal from tested 108
Power and Machinery Co.'s twin producers . 64
Producer gas 55
" " hydrogen, sulphide and sulphur dioxide in 173
" " relative merits of samples for tests .. 177

R

Radiation losses in boiler tests 14
Randall and Barnhart apparatus.. 158
Records and calculations, how made and kept 129
Richmond Railway and Coal Co., coal tested....... .... .41, 108
Ruston, Proctor and Co., Ltd., gas producer, description of . 58

PAGE

S

Samples, collection and treatment of 122
" numbering of 127
Sample tubes, use of 178
Simmance-Abady recorder 17
Soluble matter in coal 173
" " " water 173
Souris, Edmonton and Belly River coal fields, coal tested 45, 110
Specific gravity of coal 175
Split volatile ratio 156
Springhill coal field, tests of coal from . .. 43
" and Joggins coal fields, coal from tested 109
Staff, gas producer tests, duties of 80
Standard Coal Co., coals from tested 110
Stansfield, A., furnace designed by 175
" Edgar, description of gas pressure regulator 132
" " report on work of the chemical laboratory 121
Stoker, mechanical . 11, 15
Strathcona Coal Co., coal from tested . 110
Suction gas producer 58
Sulphur, determination of 140
" effect of in coal . 6
Summary of observations 23
" " results 26
Sydney coal field, coals from tested 107

T

Tables, list of in this report .Table of contents
Thermometers used in tests 18
Thomlinson, J. C., method for testing producer gas . 173

W

Washing, effect of on Pictou coal 42
Wellington Colliery Co., Ltd., coals tested 50
Welsh coal, comparison with . 35
West Canadian Collieries Co., coals tested 46
Western Dominion Collieries, Ltd., coal tested. ... .45, 110
Western Fuel Co., Ltd., coals tested 50, 117
Westinghouse double zone gas producer 64
Wilson producer gas plant 66

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Appendix V
Chemical Tests, by Edgar Stansfield

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MAPS

6. Magnetometric Survey, Vertical Intensity: Calabogie mine, Bagot township, Renfr county, Ontario—by E. Nystrom, M.E., 1904

13. Magnetometric Survey of the Belmont Iron Mines, Belmont township, Peterborough coun Ontario—by B. F. Haanel, B.Sc., 1905

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41. Survey of Victoria Road Pea [illegible] Be ley and Carden townships, Victoria county, Onta by Erik Nyström, M.E. [illegible], Peat Expert.

48. Magnetometric Map of Ir [illegible] m at Klaanch river, Vancouver island, B. Einar Lindeman, M.E.

49. Magnetometric Map of W [illegible] iron claim, at Sechart, Vancouver island, B. Einar Lindeman, M.

50. Vancouver island, B.C.—by Einar Lindeman, M.E.

51. Iron Mines, Texada island, B.C.—by E. H. Shepherd, C.E.

52. Sketch Map of Bog Iron Ore Deposits, West Arm, Quatsino sound, Vancouver island, B by L. Frank.

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60. Magnetometric Survey of the Bristol mine, Pontiac county, Quebec—by Einar Lind M.E.

61. Topographical Map of Bristol mine, Pontiac county, Quebec—by Einar Lindeman, M.

64. Index Map of Nova Scotia: Gypsum—by W. F. Jennison, M.E.

65. Index Map of New Brunswick: Gypsum—by W. F. Jennison, M.E.

66 Map of Magdalen Islands, Que. — by W. F. Jennison, M.E.

70 Magnetometric Survey of Northwest Arm Iron Range, Lake Timagami, Nipissing district, Ontario — by Einar Lindeman, M.E.

72 Brunner Peat Bog, Ontario — by A. Anrep, Peat Expert.

73 Komoka Peat Bog, Ontario — by A. Anrep, Peat Expert.

74 Brockville Peat Bog, Ontario — by A. Anrep, Peat Expert.

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6 Alfred Peat Bog, Ontario — by A. Anrep, Peat Expert.

77 Alfred Peat Bog, Ontario: Main Ditch profile — by A. Anrep, Peat Expert.

8 Map of Asbestos Region, Province of Quebec, 1910 — by Fritz Cirkel, M.E.

86 Map showing general distribution of Serpentine in the Eastern Townships — by Fritz Cirkel, M.E.

94 Map showing Cobalt, Gowganda, Shiningtree, and Porcupine districts — by L. H. Cole, B.Sc.

5 General Map of Canada, showing Coal Fields. (Accompanying report No. 83) — by Dr. J. B. Porter.

96 General Map of Coal Fields of Nova Scotia and New Brunswick. (Accompanying Report No. 83) — by Dr. J. B. Porter.

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06 Austin Brook Iron Bearing district, Bathurst township, Gloucester county, N.B. — by E. Lindeman, M.E.

Magnetometric Survey, Vertical Intensity: Austin Brook Iron Bearing district — by E. Lindeman, M.E.

8 Index Map showing Iron Bearing Area at Austin Brook — by E. Lindeman, M.E.

Sections of Diamond Drill Holes on Iron Ore Deposits at Austin Brook — by E. Lindeman, M.E.

Torbrook Iron Bearing District, Annapolis county, N.S. — by Howells Fréchette, M.Sc.

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40 Mica: Showing Distribution of the Principal Mica Occurrences in the Dominion of Canada — by Hugh S. de Schmid.

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3 Holland Peat Bog, Ontario — by A. Anrep, Peat Expert.

6 Distribution of Iron Ore Sands of the Iron Ore Deposits on the North Shore of the River and Gulf of St. Lawrence, Canada — by Geo. C. Mackenzie, B.Sc.

2 Map showing the location of peat bogs investigated in Ontario — by A. Anrep, Jr.

3 Map Showing the location of peat bogs investigated in Manitoba — by A. Anrep, Jr.

Note.—The addition of 200 to the number of a coal signifies a washed coal. The suffix "M" signifies a mixed coal.

No. [illegible]	No. [illegible]	No. [illegible]	NAME OF COLLIERY	TREATMENT AT COLLIERY
38	40	[illegible]	Western Dominion Collieries Ltd., Taylorton, Sask	Run of mine coal
39	42	[illegible]	Rosedale Coal Co. Ltd., Edmonton, Alta	Over bar screen, 1½" openings
40	43	[illegible]	Canada West Coal Co., Ltd., Taber, Alta	53 sacks of lump and 22 sacks of nut, representing screened coal over ¾" picking screen
41	44	66	Galt colliery, Alberta Ry. & Irrigation Co. Ltd., Lethbridge, Alta	Over ¾" screen and picking belt
42	[illegible]	67	Seven Foot seam, No. 1 Byron, Leitch colliery, Leitch Collieries, Ltd., Passburg, Alta	Run of mine coal
43	32	50	Hillcrest colliery, Hillcrest Coal & Coke Co., Hillcrest, Alta	Run of mine coal
44	232	51		
45	[illegible]	53	No. 1 seam, Bellevue colliery, West Canadian Collieries Co., Ltd., Blairmore, Alta	Run of mine coal
46	233	54		
47	34	55	No. 2 seam, Denison colliery, International Coal & Coke Co., Ltd., Coleman, Alta	Run of mine coal
48	234	56		
49	31	34	No. 3 mine, Michel colliery, Crowsnest Pass Coal Co., Michel, B.C	Coal passed over grizzly
50	231	52		
51	30	35	No. 7 mine, Michel colliery, Crowsnest Pass Coal Co., Michel, B.C	Coal passed over 2" grizzly and picking belt 35 feet long
52	29	36	No. 8 mine, Michel colliery, Crowsnest Pass Coal Co., Michel, B.C	Coal passed over 2" grizzly and picking belt 35 feet long
53	51	69	No. 2 seam south, Hosmer Mines Ltd., Hosmer, B.C	Slate picked out at McGill
54	52	70	No. 6 seam south, Hosmer Mines, Ltd., Hosmer, B.C	Slate picked out at McGill
55	27	37	No. 2 mine, Coal Creek, Crowsnest Pass Coal Co., Ltd., Fernie, B.C	Dumped on 2" shaking screen and passed over 70 ft. picking table
56	26	43	No. 5 mine, Coal Creek, Crowsnest Pass Coal Co., Ltd., Fernie, B.C	Dumped on 2" shaking screen and passed over 70 ft. picking table
57	25	45	No. 1 or Old mine, H. W. McNeil Co., Ltd., Canmore, Alta	Dumped on a grizzly, lump goes over a picking table, then is remixed with slack coal
58	225	49		
59	23 M	46	Bankhead colliery, Bankhead Mines Ltd., Bankhead, Alta	Mixture of 60 bags pea coal and 60 bags of buckwheat coal
60	223 M	47		
61	24	48	Briquettes, Bankhead colliery, Bankhead Mines Ltd., Bankhead, Alta	Coal dust briquettes, using rather more than 9 per [illegible]
62	22 M	40	Jewel seam, No. 1; Rat Hole seam, No. 2; Middlesboro colliery, Nicola Valley Coal & Coke Co., Coutlee, B.C	Mixture of 140 bags from No. 1 and 10 bags from No. 2 mine.
63	222 M	42		
64	20	33	Wellington seam, Wellington Colliery Co., Ltd., Cumberland, B.C	Coal passed over 1½" screen and picking table
65	18	39	Upper seam, No. 1 mine, Western Fuel Co., Ltd., Nanaimo, B.C	
66	17	38	Lower seam, No. 1 mine, Western Fuel Co., Ltd., Nanaimo, B.C	Coal passed over 2" screen and picking table 35 feet long
67	21 M	41	Lower seam, No. 4 and No. 7 mine, Comox colliery, Wellington Colliery Co., Ltd., Cumberland, B.C.	Mixture of 7488 pounds from No. 4 with 9100 pounds from No. 7 mine
68	221 M	44	Lower seam, No. 4 and No. 7 mine, Comox colliery, Wellington Colliery Co., Ltd., Cumberland, B.C.	
69	Ex 234	71	Suquash mine, Pacific Coast Coal Co., Ltd., Alert bay, Vancouver island	

TABLE IV

SUMMARY RECORD OF

6	7	8	9	10	11	12	12	15	16	17	18	19	20	21	22
Date of Trial	Duration of Trial	Proximate Analysis			Moisture in Coal as Fired	Weight Coal as Fired	Weight Dry Coal	Weight Ash	Ash and Clinker in Dry Coal	Weight Feed Water	Dry Coal		Combustible per Sq. Ft. Grate Per Hour	Steam Per Hour Corrected for Moisture	[illegible] at 212°
		Fixed Carbon	Volatile Matter	Ash							Per Hour	Per Hour Per Sq. Ft. Grate			
	Hours	%	%	%	%	Lbs.	Lbs.	Lbs.	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
12-8-08	8·70	42·9	49·0	8·1	29·7	4,580	3,219	113	8·2	15,164	370·0	22·1	31·5	1,736	[illegible]
10-9-08	10·00	51·3	37·8	10·9	19·7	4,184	3,336	265	11·4	17,431	335·0	19·9	24·9	1,735	2,060
8-9-08	10·00	49·9	36·0	14·1	11·3	4,403	3,906	119	17·3	18,290	390·5	23·3	26·3	1,812	[illegible]
11-9-08	6·50	51·5	37·5	11·0	8·3	2,442	2,240	46	10·4	12,170	345·0	[illegible]	22·1	1,863	[illegible]
14-9-08	10·25	55·1	27·0	17·9	0·9	3,004	2,977	95	17·0	16,783	290·0	17·4	17·4	1,630	1,936
13-7-08	10·02	55·4	29·3	15·3	0·8	2,665	2,644	128	15·5	17,171	264·0	15·7	15·8	1,708	2,029
15-7-08	10·00	60·4	29·8	9·8	3·8	2,722	2,618	97	[illegible]	17,860	262·0	[illegible]	16·2	1,778	2,111
20-7-08	10·00	56·9	27·6	15·5	0·8	2,811	2,789	89	14·1	17,550	279·0	16·6	16·7	1,748	2,083
22-7-08	10·03	58·9	28·4	12·7	3·6	2,837	2,734	87	10·5	17,730	274·0	16·2	16·8	1,761	2,092
24-7-08	10·00	55·1	25·1	19·8	0·8	2,811	2,789	126	18·8	17,018	279·0	16·6	16·7	1,693	2,013
27-7-08	10·05	62·0	26·4	11·6	3·7	2,782	2,679	120	10·6	17,858	266·0	15·8	16·4	[illegible]	[illegible]
5-6-08	10·00	62·7	24·8	12·5	0·7	2,702	2,683	78	11·4	18,233	268·0	15·9	16·0	1,814	[illegible]
17-6-08	10·00	68·6	25·2	6·2	4·9	2,604	2,476	98	7·4	17,933	248·6	14·7	15·5	1,785	[illegible]
10-6-08	10·00	65·5	22·6	11·9	1·0	2,653	2,627	104	12·7	18,000	263·0	15·7	15·9	1,793	[illegible]
6-10-08	10·03	65·7	24·1	10·2	1·0	2,615	2,589	100	10·0	18,038	258·0	15·4	15·6	1,784	2,145
4-9-09	10·03	63·4	21·3	15·3	1·1	2,593	2,564	74	15·3	17,133	256·0	15·2	15·4	1,698	2,027
24-9-09	10·00	62·0	25·6	12·4	1·5	2,771	2,730	85	16·2	17,674	273·0	16·3	16·5	1,756	2,096
12-6-08	10·00	64·7	26·3	9·0	1·0	520	2,495	91	9·6	18,295	249·0	[illegible]	15·0	1,820	2,182
26-6-08	10·00	65·2	24·0	10·8	1·0	2,671	2,644	78	10·8	18,519	264·4	15·8	16·0	1,845	[illegible]
30-6-08	10·05	70·5	17·2	12·3	0·8	2,777	2,755	153	15·6	18,080	274·3	16·4	16·5	1,800	2,147
10-6-08	10·00	77·9	16·2	5·9	4·3	2,515	2,407	76	8·9	17,922	240·7	14·3	14·9	1,785	2,122
3-7-08	10·00	73·3	12·6	14·1	0·6	2,530	2,515	80	15·6	15,609	251·5	15·0	15·1	1,556	1,850
6-7-08	10·00	78·6	12·5	8·9	2·7	2,535	2,467	42	9·5	17,497	247·0	14·7	15·0	1,744	2,075
7-7-08	10·00	68·6	17·1	14·3	0·7	2,666	2,648	101	15·2	16,421	264·8	15·8	15·9	1,636	1,942
19-6-08	10·00	46·8	39·1	14·1	4·8	3,418	[illegible]	115	[illegible]	17,720	325·0	[illegible]	[illegible]	1,765	[illegible]
24-6-08	10·00	50·2	39·8	10·0	6·2	3,457	3,243	87	10·4	18,131	324·3	19·3	20·6	1,813	[illegible]
3-6-08	10·05	49·8	40·1	10·1	1·4	3,163	3,119		[illegible]	17,825	310·0	18·4	18·7	1,764	[illegible]
17-6-08	10·00	48·5	41·2	10·3	2·3	3,266	3,191		8·7	18,060	319·0	19·0	[illegible]	1,799	[illegible]
15-6-08	10·00	46·6	41·5	11·9	2·1	3,566	3,511	[illegible]	11·4	18,635	351·0	20·9	21·3	[illegible]	[illegible]
22-6-08	10·00	57·8	30·2	12·0	1·0	2,852	2,804		10·8	[illegible]	280·0	[illegible]	16·9	1,755	[illegible]
29-6-08	10·00	60·3	30·8	8·9	4·0	2,827	2,742	[illegible]	9·9	18,471	274·2	16·3	16·8	1,811	[illegible]
1-3-10	10·00	48·2	36·7	15·1	5·3	3,402	3,222		15·9	[illegible]	322·0	19·2	20·2	1,646	[illegible]

[illegible] RECORD OF BOILER TESTS

					Moisture in Steam	[illegible]	Water Apparently Evap.	[illegible]	[illegible]	Cal. Value per lb		Boiler Efficiency	
										[illegible]	[illegible]	[illegible]	[illegible]
							lb.			B.t.u.	B.t.u.		
	[illegible]	[illegible]		[illegible]	0.6	59	4.31	[illegible]	[illegible]	7,520	10,600	52.[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	0.29	[illegible]	60.0	4.20	4.98	7.75	8,700	10,910	64.8	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	62.7	4.15	4.91	7.07	9,790	11,040	50.9	58.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6	64.1	4.98	5.92	7.58	10,740	11,740	55.7	[illegible]
[illegible]				[illegible]	0.6	56.1	[illegible]	6.61	8.48	12,140	12,240	55.0	52.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58.8	[illegible]	[illegible]	[illegible]	[illegible]	12,400	61.4	59.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.50	7.77	[illegible]	12,900	[illegible]	59.6	58.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.41	9.20	12,280	12,480	60.6	58.3
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	60.0	6.25	7.40	[illegible]	[illegible]	[illegible]	58.2	56.9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.42	7.60	9.22	[illegible]	[illegible]	[illegible]	57.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.08	[illegible]	[illegible]	13,270	[illegible]	[illegible]
[illegible]	115.7	[illegible]	[illegible]	0.20	0.6	[illegible]	[illegible]	[illegible]	[illegible]	13,610	14,310	60.4	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	62.3	[illegible]	8.11	9.65	13,240	[illegible]	61.5	59.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.7	62.2	[illegible]	8.21	9.58	[illegible]	[illegible]	[illegible]	59.6
[illegible]	111.2	29.72	[illegible]	0.35	0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12,740	61.4	60.3
[illegible]	[illegible]	29.83	[illegible]	0.21	0.6	60.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	61.7	56.6
[illegible]	[illegible]	29.88	[illegible]	0.20	0.6	[illegible]	7.20	8.66	[illegible]	[illegible]	[illegible]	[illegible]	61.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	62.2	59.7
[illegible]	[illegible]	[illegible]	[illegible]	0.35	[illegible]	[illegible]	[illegible]	7.74	9.82	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	0.51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14,400	[illegible]	59.2
[illegible]	[illegible]	[illegible]	[illegible]	.87	[illegible]	[illegible]	[illegible]	[illegible]	9.77	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.20	9.88	[illegible]	[illegible]	62.1	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58.4	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11,720	54.8	[illegible]
	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	6.22	7.67	[illegible]	12,620	52.8	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13,160	[illegible]	50.3
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	62.1	[illegible]	6.59	7.71	12,540	[illegible]	52.1	50.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6	[illegible]	5.20	6.17	7.30	12,210	12,470	49.8	49.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.25	7.41	8.68	[illegible]	13,010	56.7	55.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.08	8.95	13,180	[illegible]	57.9	56.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.88	5.92	8.11	10,950	11,580	57.5	52.7

38 Dry Flue Gas per lb. Dry Coal	39 Heat of Flue Dry Gas	40 Temp. of Escaping Flue Gases at Damper	41 Treatment of Coal When Burnt	General Remarks	
Lbs.					
3[illegible]·2	1[illegible]	578	Fire [illegible] to most [illegible] of grate	[illegible] of fire [illegible] smoke	[illegible]
[illegible]4·7	14·4	532	Grate [illegible] fire opened [illegible]	Clinker difficult to [illegible] steam was used [illegible] grate could be used with steam	[illegible]
[illegible]·2	17·0	627	Air over fire, steam under bars	Clinker [illegible] with steam [illegible] grate could be used with steam	10
1[illegible]·6	13·[illegible]		Steam [illegible]	Clinker [illegible] with steam	11
20·9	17·0	[illegible]	Bars with [illegible] air space used, fire [illegible] thick	No [illegible] difficulty, shaking grate suitable [illegible] moderately [illegible] heavy smoke	12
[illegible]·0	16·6	572		Steam [illegible] adhesive [illegible] shaking grate suitable, coal cakes moderately	13
19·[illegible]	17·1	578	Fire [illegible] owing to small size of coal	Clinker very [illegible] suitable for shaking grate, cakes less than No. 12	14
18·7	18·8	506		Clinker fairly [illegible] suitable for shaking grate, cakes badly, dense smoke	15
18·2	17·6	600		Clinker fairly [illegible] suitable for shaking grate, coal cakes badly, smoke rather dense	16
19·9	20·9	600	Burnt a fairly thick fire, using forced draught.	Clinker chiefly cinders, suitable for shaking grate, coal cakes badly, smoke rather dense	47
17·9	17·6	623		Clinker harder and coal cakes [illegible] than No. 31, shaking grate suitable, smoke fairly dense	48
19·9	16·5	541	Steam not used, sliced 3 times	Clinker hard, heavy, and adherent until steam used, shaking grate could be used with steam, coal cakes, smoke light	49
21·4	19·4	621		Clinker in thin, hard layer, could not use on a shaking grate; coal cakes	50
21·0	17·1	538	Fire kept fairly thick	Clinker light, friable and easily removed; coal cakes a little, light smoke	51
22·1	19·5	573	Fire kept fairly thick	Clinker light, friable, and easily removed; coal cakes a little, light smoke	52
2[illegible]·0	15·4	412	At first natural draught and thin fire, later forced draught, thick fire	Clinker soft and easily removed, suitable for shaking grate, cakes a little, [illegible] smoke; fire bars with ¼" air space	53
[illegible]5·7	18·7	472	At first natural draught and thin fire, later forced draught, thick fire	Clinker in hard porous slabs, fairly easy to remove, coal cakes rather badly; considerable smoke; fire bars with ¼" air space	54
20·9	18·3	582	Steam used under bars	Clinker in thin hard layer, easily removed; fair amount of smoke.	55
[illegible]7·2	15·6	504		Clinker soft and easily removed, could be used on shaking grate; coal cakes, much flame and brown heavy smoke	56
19·8	20·5	647	Steam used under bars rendered clinker soft	Clinker hard, shaking grate could be used with steam, little smoke	[illegible]
23·0	17·9	554	Burnt thick bed with forced draught and steam jet	Hard layer of clinker sticking to bars until steam was put on, shaking grate might be used with steam, very little smoke	[illegible]
21·9	19·6	[illegible]	Burnt thick bed with forced draught	Clinker very soft and easily removed, very suitable for shaking grate; no smoke	59
2[illegible]·[illegible]	18·3	[illegible]	Burnt thick bed with forced draught	Clinker very soft and easily removed, very suitable for shaking grate; no smoke	60
25·2	23·9	590	Burnt thick bed with forced draught	Clinker in large soft porous lumps, suitable for shaking grate, little smoke	[illegible]
[illegible]6·9	17·9	603		Clinker soft and easy to remove, very suitable for shaking grate, much flame and smoke	[illegible]
14·5	16·1	670	Air over fire	Clinker principally cinders, very suitable for shaking grate, much smoke	
19·4	15·6	518		Clinker thin, hard, and adherent, dense smoke	64
17·2	15·8	572	Thin fire, air over fire, steam under bars	Clinker hard and adherent, medium smoke	[illegible]
17·5	16·8	578	Steam under bars	Hard, heavy, and adherent clinker	66
19·0	18·0	593		Clinker porous and easily removed, suitable for shaking grate	67
18·2	17·5	629	Steam under bars softens clinker.	Clinker hard and troublesome, shaking grate could be used with steam, coal cakes	68
		374	Fire [illegible] thick, steam under bars	Rather [illegible] clinker, difficult to remove	[illegible]

* 1,800 lbs. coal in addition to the amount stated was used in starting and banking the fires, but is not accounted for in this table. **Steam used for about one hour.

1	2	3	4	
No. of Line	No. of Coal	No. of Trial	NAME OF COLLIERY AND COMPANY	T
1	36	32	Dominion No. 7, Hub seam. Dominion Coal Co., Ltd., Glace Bay, N.S.	Over 2
2	35	31	Dominion No. 9, Harbour seam. Dominion Coal Co., Ltd., Glace Bay, N.S.	Over 2
3	38	34	Dominion No. 1, Phalen seam. Dominion Coal Co., Ltd., Glace Bay, N.S.	Over 1
4	37	33	Dominion No. 10, Emery seam. Dominion Coal Co., Ltd., Glace Bay, N.S.	Run o
5	12	30	No. 3 colliery. Nova Scotia Steel & Coal Co., Sydney Mines, N.S.	Over
6	15	21	Port Hood colliery. Richmond Ry. Coal Co., Port Hood, N.S.	Over
7	2	24	Cage Pit seam, Albion colliery. Acadia Coal Co., Ltd., Stellarton, N.S.	Run o
8	8	26	Main seam, Acadia. Acadia Coal Co., Ltd., Westville, N.S.	Over 1
9	3	23	Main seam, Drummond colliery. Intercolonial Coal Co., Westville, N.S.	Over 1
10	5	22	No. 2 colliery. Cumberland Ry. & Coal Co., Springhill, N.S.	Over
11	10	27	Joggins colliery. Canada Coal & Ry. Co., Ltd., Joggins, N.S.	Over
12	11	20	King's mine. S. H. King, Minto, N.B.	Over
13	2040	8	Western Dominion Collieries Ltd., Taylorton, Sask.	Run o
14	2040	17	Western Dominion Collieries Ltd., Taylorton, Sask.	Run o
15	42	15	Parkdale Coal Co., Ltd., Edmonton, Alta.	Over 1
16	45	10	Standard Coal Co., Edmonton	Over
17	46	11	Strathcona Coal Co., Strathcona, Alta.	15
18	43	12	Canada West Coal Co., Ltd., Taber, Alta.	53
19	44	13	Galt colliery. Alberta Ry. & Irrigation Co., Ltd., Lethbridge, Alta.	Over
20	40, 42, 43, 44, 46	16	....	......
21	48	14	Leitch colliery. Leitch Collieries Ltd., Passburg, Alberta.	Run o
22	34	36	No. 2 seam, Denison colliery. International Coal & Coke Co., Coleman, Alta.	Run o
23	29	35	No. 5 mine, Michel colliery. Crowsnest Pass Coal Co., Fernie, B.C.	Coal p
24	26	40	No. 5 mine, Coal Creek. Crowsnest Pass Coal Co., Fernie, B.C.	Dump
25	27, 30	42	No. 2 mine, Coal Creek. Crowsnest Pass Coal Co., Fernie, B.C. No. 7 mine, Michel colliery, Michel, B.C.	Dump
26	25	37	No. 1 or Old mine. H. W. McNeil Co., Ltd., Canmore, Alta.	Dump
27	25	38	No. 1 or Old mine. H. W. McNeil Co., Ltd., Canmore, Alta.	Dump
28	23M	41	Bankhead colliery. Bankhead Mines, Ltd., Bankhead, Alta.	Mixtu
29	22M	18	Jewel seam, No. 1; Rat Hole seam, No. 2; Middlesboro colliery. Nicola Valley Coal & Coke Co., Coutlee, B.C.	Mixtu
30	22M	25	Jewel seam, No. 1; Rat Hole seam, No. 2; Middlesboro colliery. Nicola Valley Coal & Coke Co., Coutlee, B.C.	Mixtu
31	18	20	Upper seam, No. 1 mine, south side, Western Fuel Co., Nanaimo, B.C.	......
32	17	19	Lower seam, No. 1 mine, north level. Western Fuel Co., Nanaimo, B.C.	Coal p
1	2	3	4	

5	6	7	8	9	10	11
TREATMENT AT THE MINES. ALL SAMPLES WERE ALSO SCREENED THROUGH 3 INCH AND OVER ½ INCH AT MCGILL UNIVERSITY	Date of Trial	Duration of Trial	Proximate Analysis of Coal as Charged			
			Fixed Carbon	Volatile Matter	Ash	Moisture
		Hours	%	%	%	%
Over 2½" shaking screen and picking belt.	8-9-3-09	24	57·6	35·0	5·0	2·4
Over 2½" bar screen and picking table.	4-5-3-09	24	52·6	35·1	10·9	1·4
Over 1" screen and picking table.	15-16-3-09	24	58·8	32·5	6·5	2·2
Run of mine	11-12-3-09	24	52·6	34·2	11·1	2·1
Over ½" screen and picking belt.	1-2-3-09	24	53·2	35·4	7·8	3·6
Over ¾" shaking screen and picking belt.	17-18-1-09	24	49·2	35·3	12·7	2·8
Run of mine	28-29-1-09	24	56·3	30·9	10·9	1·9
Over 1" screen and picking belt	15-16-2-09	24	61·6	27·5	9·0	1·9
Over 1" screen and picking belt	25-26-1-09	23	62·7	24·0	12·0	1·3
Over ¾" screen and picking belt	21-22-1-09	24	59·4	31·4	7·3	1·9
Over ¾" screen and picking belt	18-19-2-09	24	45·0	34·4	18·1	2·5
Over ¾" screen, no picking belt	25-26-2-09	24	53·3	32·7	12·7	1·3
Run of mine coal	16-17-11-08	24	36·7	32·8	7·2	23·3
Run of mine coal	4-5-1-09	10	32·2	43·3	11·1	13·4
Over bar screen 1½" openings	10-11-12-08	24	42·8	28·7	11·2	17·3
Over short bar screen 1½" openings	23-24-11-08	20	46·0	31·2	7·5	15·3
15 sacks over 2½" bar screen and 10 sacks over 1½" bar screen; representing screened coal over 1½" screen	26-27-11-08	17½	41·1	30·9	11·9	16·1
53 sacks of lump and 22 sacks of nuts; representing screened coal over ¾" shaking screen	30-11-08-1-12-08	24	44·5	26·6	16·3	12·6
Over ¾" screen and picking table.	3-4-12-08	24	47·6	35·2	9·4	7·8
....	15-17-12-08	28	40·8	31·1	9·6	18·6
Run of mine coal	7-8-11-08	24	51·1	29·2	18·7	1·0
Run of fine coal	22-23-3-09	24	56·4	24·4	18·1	1·1
Coal passed over 2" grizzly and picking belt 35 feet long	18-19-3-09	24	67·8	25·1	6·0	1·1
Dumped on 2" shaking screen and passed over 70 ft. picking table	5-6-4-09	24	62·7	25·6	10·9	0·8
Dumped on 2" shaking screen and over picking belt. Passed over 2" grizzly and 35 ft. picking belt	13-24-4-09	100	64·64	24·82	9·57	0·97
Dumped on a grizzly, lump goes over a picking table; lump remixed with slack coal.	25-26-3-09	24	70·5	15·6	13·0	0·9
Dumped on a grizzly, lump goes over a picking table; lump remixed with slack coal	29-30-3-09	23	70·3	16·7	12·3	0·7
Mixture of 60 bags of pea coal and 60 bags of buckwheat coal	8-9-4-09	24	77·7	11·4	9·9	1·0
Mixture of 140 bags from No. 1 and 10 bags from No. 2 mine	7-8-1-09	24	47·8	36·2	12·8	3·2
Mixture of 140 bags from No. 1 and 10 bags from No. 2 mine	8-9-2-09	24	46·9	36·9	12·0	4·2
....	14-15-1-09	24	44·5	40·3	13·7	1·5
Coal passed over 2" screen and 35 ft. long picking table	11-12-1-09	23	41·5	39·7	16·8	2·0
5	6	7	8	9	10	11

	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Duration of Trial	Proximate Analysis of Coal as Charged				Calorific Value of Coal as Charged	Weight of Coal Charged	Weight of Dry Coal Charged	Refuse Removed During Trial Prox. Analysis		Average Depth of Fuel Bed Above Orifice	Total Gas as Metered During Trial	Average Temp. of Gas Leaving Producer	Average Higher Calorific Value of Gas (As Metered) By Calorimeter
		Fixed Carbon	Volatile Matter	Ash	Moisture				Fixed Carbon	Volatile Matter				
	Hours	%	%	%	%	B.T.U.	Lbs.	Lbs.	%	%	Inches	Cubic Feet	°F.	B.T.U. Per Cub. Ft.
09	24	57·6	35·0	5·0	2·4	13,520	1,450	1,415	38·1	4·7	43·0	79,240	783	112·8
09	24	52·6	35·1	10·9	1·4	13,800	1,400	1,380	64·1	4·4	40·0	77,530	785	110·3
9	24	58·8	32·5	6·5	2·2	13,700	1,650	1,613	67·3	7·7	42·0	81,840	716	116·3
09	24	52·6	34·2	11·1	2·1	12,840	1,450	1,420	47·6	3·6	43·0	82,330	812	105·9
09	24	53·2	35·4	7·8	3·6	13,180	1,200	1,156	45·0	7·2	43·7	81,320	732	105·7
09	24	49·2	35·3	12·7	2·8	11,440	1,950	1,895	57·5	5·4	38·0	76,650	780	125·2
09	24	56·3	30·9	10·9	1·9	12,920	1,175	1,152	37·8	4·3	42·0	89,685	875	99·3
09	24	61·6	27·5	9·0	1·9	13,600	1,450	1,422	63·8	2·7	43·0	85,630	827	99·8
09	23	62·7	24·0	12·0	1·3	12,780	1,100	1,086	53·1	4·8	40·0	86,600	824	101·5
09	24	59·4	31·4	7·3	1·9	13,120	1,375	1,348	55·8	6·0	42·0	87,535	757	100·7
09	24	45·0	34·4	18·1	2·5	11,300	1,425	1,389	43·0	5·8	42·0	80,530	769	105.5
09	24	53·3	32·7	12·7	1·3	12,720	1,125	1,110	49·8	5·7	43·3	80,170	773	104·5
08	24	36·7	32·8	7·2	23·3	8,300	1,625	1,247	Analysis Not Taken		35·0	71,595	529	118·0
09	19	32·2	43·3	11·1	13·4	9,370	1,475	1,278	38·0	9·8	34·0	59,200	529	124·2
08	24	42·8	28·7	11·2	17·3	8,940	1,925	1,590	28·9	8·4	39·6	75,375	594	128·1
08	20	46·0	31·2	7·5	15·3	9,610	1,261	1,070	Analysis Not Taken		44·0	60,135	517	124·5
08	17¾	41·1	30·9	11·9	16·1	9,010	1,132	950	27·9	6·5	40·0	59,018	581	124·3
08	24	44·5	26·6	16·3	12·6	9,650	1,725	1,508	47·7	5·7	43·5	77,705	557	124·1
08	24	47·6	35·2	9·4	7·8	10,800	1,550	1,430	31·5	9·1	47·8	74,603	572	128·3
08	28	40·8	31·1	9·6	18·6	8,900	2,365	1,922	40·0	9·0	35·1	86,760	524	131·3
08	24	51·1	29·2	18·7	1·0	12,120	1,700	1,683	50·8	3·3	40·0	81,840	743	108·0
09	24	56·4	24·4	18·1	1·1	11,590	1,325	1,310	29·2	4·2	41·7	86,080	739	102·3
09	24	67·8	25·1	6·0	1·1	13,330	1,375	1,360	62·6	3·5	43·3	86,535	710	104·1
09	24	62·7	25·6	10·9	0·8	13,370	950	942	33·4	6·1	43·8	93,100	725	100·2
	100	64·64	24·82	9·57	0·97	13,580	4,250*	4,207*	60·7	5·3	41·0	396,810	730	95·6
09	24	70·5	15·6	13·0	0·9	13,100	1,350	1,339	58·7	3·1	43·7	91,995	706	91·6
09	23	70·3	16·7	12·3	0·7	13,120	961	955	38·9	5·8	32·7	90,940	772	90·7
09	24	77·7	11·4	9·9	1·0	12,950	1,125	1,114	46·2	4·4	41·3	88,460	699	107·0
09	24	47·8	36·2	12·8	3·2	11,340	2,075	2,009	64·7	5·7	40·0	72,385	740	132·3
09	24	46·9	36·9	12·0	4·2	11,220	1,350	1,292	48·6	2·8	42·8	89,150	848	106·8
09	24	44·5	40·3	13·7	1·5	12,640	1,350	1,330	56·0	7·0	40·0	72,795	656	130·9
09	22	41·5	39·7	16·8	2·0	12,220	1,675	1,640	65·0	6·2	42·[illegible]	63,050	634	138·3
	7	8	9	10	11	12	13	14	15	16	17	18	19	20

TABLE XXXIII SUMMARY RECORD OF GAS PRODUCER TESTS.

20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
erage igher lorific e of Gas Metered) By rimeter	Average Higher Calorific Value of Gas at 60°F. and 14·7 Lbs. Sq. In., By Calorimeter	Average Lower Calorific Value (Column 21 corrected from gas analyses)	Average Analysis of Gas by Volume							Average Suction at Producer	Average Mean Eff. Pressure Gas Engine Cylinder Indicator)	Average B.H.P Corr. for Gas Blown Off	Average B.H.P. (Net) (Col. 32 Less Power For Auxiliaries	Coal Charged Per Hour
			CO_2	O_2	CO	H_2	CH_4	C_2H_4	N_2					
U. Per b. Ft.	B.T.U. Per Cub. Ft.	B.T.U. Per Cub. Ft.	%	%	%	%	%	%	%	Inches of Water	Lbs. Per Sq. In.			Lbs
12·8	115·7	106·5	10·9	0·5	11·4	11·4	3·2	0·1	62·5	1·0	69·6	25·2	21·2	60·4
10·3	116·4	107·3	10·0	0·4	11·8	10·5	3·7	0·2	63·4	1·6	70·1	26·3	22·3	58·3
16·3	120·0	110·0	10·1	0·8	10·7	12·5	3·3	0·2	62·4	1·8	67·1	26·2	22·2	68·75
05·9	108·9	100·3	10·8	0·4	11·9	11·4	2·7	0·0	62·8	1·5	61·6	25·2	22·7	60·4
05·7	108·8	98·0	12·5	0·4	11·2	13·7	3·1	0·1	59·0	0·8	70·3	28·4	24·4	50·0
25·2	125·0	116·1	11·0	0·8	11·9	11·0	2·8	0·4	62·1	1·5	68·2	29·2	25·2	81·25
99·3	102·7	93·6	11·8	1·1	11·2	12·1	2·6	0·2	61·0	1·1	61·6	[illegible]	22·8	49·0
99·8	101·3	91·9	10·8	0·7	10·2	11·9	3·1	0·2	63·1	1·5	62·3	26·5	22·5	60·4
101·5	106·0	97·7	11·4	0·5	12·2	11·6	2·2	0·2	61·9	2·2	64·5	27·1	22·1	47·8
100·7	104·0	93·8	11·7	1·2	10·4	12·4	3·5	0·2	60·6	0·9	63·8	27·7	23·7	57·3
105.5	107·2	98·9	10·4	0·8	12·1	10·6	2·7	0·1	63·3	1·8	67·2	28·2	24·2	59·4
104·5	108·2	98·3	9·2	0·6	13·7	12·1	3·4	0·2	60·8	1·0	60·8	27·7	23·7	46·8
118·0	122·4	112·7	11·7	0·9	15·05	11·48	3·75	0·00	57·12	3·3	65·2	29·7	26·2	67·7
124·2	128·3	117·4	11·6	1·0	13·3	14·0	3·6	0·1	56·4	1·7	73·1	31·3	28·8	77·7
128·1	130·0	119·5	11·02	0·63	14·5	12·9	3·7	0·05	5·72	1·5	72·1	30·7	28·2	80·2
124·5	129·5	118·6	11·16	0·62	15·07	13·76	3·68	0·0	55·71	1·8	61·7	29·6	26·1	63·0
124·3	130·2	119·0	12·0	0·4	14·68	15·0	3·3	0·02	54·6	1·0	67·0	34·8	31·3	63·7
124·1	131·0	120·0	11·53	0·65	12·79	15·22	3·08	0·00	56·73	1·5	68·7	29·5	26·0	71·9
128·3	134·0	122·4	10·9	0·42	13·46	14·74	3·87	0·10	56·51	1·0	70·1	30·4	26·9	64·6
131·3	133·8	122·2	12·11	0·36	14·38	14·98	3·61	0·1	54·5	1·1	74·7	30·3	27·8	84·5
108·0	112·2	103·9	8·9	2·0	10·3	8·0	4·1	0·1	66·6	2·0	67·0	25·8	22·3	70·8
102·3	105·8	97·3	11·7	0·5	12·3	11·7	2·4	0·1	61·3	1·2	64·2	25·7	21·7	55·2
104·1	110·2	102·3	9·8	0·5	13·7	9·9	2·6	0·1	63·4	1·1	63·5	25·7	21·7	[illegible]
100·2	103·6	95·2	12·9	0·5	11·6	12·0	2·2	0·0	60·8	1·1	57·8	25·8	21·8	[illegible]
95·6	98·9	89·9	12·72	0·41		12·95	2·21	0·07	59·9	1·6	66·5	27·7	24·3	42·5
91·6	97·9	89·4	12·1	0·5		11·8	2·3	0·1	62·0	1·1	56·5	23·8	19·8	50·2
90·7	95·4	87·2	13·2	0·6	10·5	11·9	2·1	0·1	61·6	1·3	55·9	24·2	[illegible]	[illegible]
107·0	111·0	102·1	11·7	0·2	12·8	13·1	2·2	0·0	60·0	2·3	58·47	26·3	[illegible]	
132·3	136·4	122·9	10·74	0·5	11·8	12·3	6·48	0·68	57·5	2·5	69·46	23·8	[illegible]	
106·8	107·9	99·3	10·8	1·2	11·7	10·7	2·8	0·2	62·6	1·7	68·9	28·4	24·4	
130·9	135·4	124·5	10·5	0·6	11·6	11·9	4·3	0·5	60·6	2·7	67·83	29·8	25·8	50·2
138·3	142·1	130·4	11·0	0·3	10·0	12·5	4·6	0·6	61·0	1·7	[illegible]	30·3	26·8	70·1
20	21	22	23	24	25	26	27	28	29	30	31	32	33	34

35	36	37	38	39	40	41	42	43	
Coal Charged Per Sq. Ft Fuel Bed Per Hour	Coal Per B.H.P (Gross) Per Hour	Coal Per B.H.P (Net) Per Hour	Standard Gas (at 14·7 Lbs. Sq. In., and 60°F.) Per Hour	Standard Gas Per Lb of Coal	Steam used Per Lb. of Coal	Water used Per Lb. of Coal	Efficiency of Producer based on Cal. Value of Gas and of Coal Charged	B.T.U. In Coal Charged Per B.H.P. Hour	
Lbs	Lbs.	Lbs.	Cubic Feet	Cubic Feet	Lbs.	Lbs.	%		
15·1	2·40	2·85	3,220	53·3	1·5	24·8	42·0	32,450	Gas washer gave trouble 91 pounds of tar removed; engine valves in g
14·6	2·21	2·61	3,058	52·5	1·5	23·7	40·8	30,500	Gas washer blown through with steam 6 times; gas delivered to atmosphe
17·2	2·63	3·10	3,303	48·1	1·3	23·7	38·5	36,030	Gas washer blown through with steam once; 137 pounds of tar removed
15·1	2·39	2·66	3,333	55·2	1·5	19·9	43·2	30,690	Sawdust scrubber used in place of gas washer; 97 pounds of tar remove
12·5	1·76	2·05	3,300	66·0	1·8	30·0	49·1	23,200	Gas washer blown through with steam 4 times; 83 pounds of tar remove
20·3	2·78	3·22	3,196	39·4	1·0	18·2	39·8	31,703	Gas washer found to be packed with tar at end of trial and was cleaned
12·2	1·83	2·15	3,605	73·7	2·2	35·0	53·3	23,650	Very little trouble from tar or clinker; 7 pounds of tar removed from wes
15·1	2·28	2·68	3,510	58·2	1·4	26·6	39·3	31,010	Gas washer cleaned with steam twice; pipes cleaned out twice; 55 pounds
11·9	1·76	2·16	3,605	75·5	1·9	36·5	57·8	22,493	Steam used in gas washer no trouble from tar; 45 pounds of tar remov
14·3	2·07	2·42	3,512	61·5	1·7	29·5	43·8	27,160	Gas washer blown through with steam 5 times; 33 pounds of tar remove
14·9	2·11	2·45	3,304	55·6	1·5	25·3	48·6	23,840	Gas washer blown through with steam 3 times; 41 pounds of tar remove
11·7	1·69	1·98	3,225	69·0	1·9	28·1	53·1	21,497	Gas washer blown through with steam 4 times; 119 pounds of tar remov
16·6	2·28	2·58	2,875	42·5	**	16·3	57·8	18,924	Very little tar formed; slight tendency of fuel to arch; fire poked 5 time
19·4	2·48	2·79	3,019	38·8	0·0	11·1	48·8	23,240	No tar removed; neither gas washer nor sawdust scrubber used; 2 hours
20·1	2·61	2·84	3,086	38·5	0·0	15·6	51·4	23,330	No tar removed; neither gas washer nor sawdust scrubber used; fire pok
15·8	2·13	2·42	2,890	45·7	0·0	13·2	56·6	20,470	No difficulty from tar; fire showed a tendency to clinker and was poked
15·9	1·83	2·04	3,175	49·8	0·8	19·6	65·7	16,490	No difficulty from tar; fire showed a tendency to arch and clinker a little
18·0	2·42	2·76	3,065	42·6	1·0	17·4	53·4	23,350	Traces of tar from wet scrubber. coal shows a tendency to form clinker;
16·1	2·13	2·40	2,975	46·0	1·1	15·5	52·2	23,000	No difficulty from tar; fire poked 13 times . . . .
21·1	2·79	3·04	3,050	36·0	0·0	10·3	49·5	24,830	Commercial test lasting 3 days; fire banked at night; neither gas washer
17·7	2·71	3·17	3,280	46·3	1·2	26·0	39·7	33,210	Gas washer shut down for 3 hours for cleaning; much trouble from tar
13·8	2·14	2·54	3,470	2·9	1·7	27·6	[illegible]	24,800	Gas washer blown through with steam once; 45 pounds of tar removed;
14·3	2·23	2·64	3,408	59·5	1·6	24·0	45·7	29,730	Gas washer blown through with steam twice; 50 pounds of tar removed;
9·9	1·5[illegible]	1·82	3,750	94·7	2·8	35·9	67·6	20,460	Total tar removed 24 pounds from wet scrubber; coal showed a tendency
10·6	1·53	1·75	3,840	90·4	2·6	29·3	59·9	20,780	Trial lasted ten days; fire banked at night; gas washer used for 6 days on
14·1	2·36	2·84	3,588	63·8	1.9	25·6	43·4	30,920	Gas washer steamed once. 17 pounds of tar removed from wet scrubber;
10·5	1·72	2·07	3,760	89·9	2·9	36·5	60·0	22,566	Gas washer blown through with steam twice; 20 pounds of tar removed f
11·7	1·78	1·97	3,550	75·9	2·4	25·6	59·8	23,000	Neither gas washer nor sawdust scrubber used; fire poked 3 times . . .
21·6	3·64	4·25	2,925	33·8	1·4	10·5	36·6	41,280	The gas washer and blower were badly clogged with tar; the engine valv
14·0	1·98	[illegible]	3,676	65·5	1·5	28·2	58·2	22,200	Gas washer steamed three times; total tar collected, 30 pounds; engine
14·0	1·88	2·18	2,932	52·2	1·7	27·0	51·5	23,760	Gas washer blown through with steam once; 48 pounds of tar collected;
19·0	2·52	2·84	2,786	36·5	1·2	21·5	39·0	30,790	Trouble from tar in gas washer and on engine valves; 17 pounds of tar
35	36	37	38	39	40	41	42	43	

REMARKS

valves in good condition at end of trial; fuel required much attention re poked 24 times.

atmosphere directly twice during trial to enable the pipes to be cleaned 148 pounds tar removed; fuel required much attention: fire poked 25 times

ar removed from wet scrubber pipes and troughs; fire was poked 24 tim

tar removed; fuel required little attention

tar removed; fire poked 14 times

as cleaned with steam 4 times; 70 pounds of tar was removed; engine alves in dirty condition: fire poked 9 times

d from west scrubber; fire poked 10 times

55 pounds of tar removed; fire did not arch or clinker and was poked times; engine valves in good condition at end of trial

tar removed; engine valves were in good condition; fire poked 11 tim

tar removed from wet scrubber and 1 pound from gas washer; fire poke 23 times; engine valves in good condition at end

ar removed; engine valves slightly tarred; fire did not arch or clinker as poked 13 times.

f tar removed; fire poked 12 times

ked 5 times.

d; 2 hours before the end the baffle brick broke causing a high suction; fire poked 4 times.

d; fire poked 11 times

was poked 5 times.

ker a little; fire poked twice.

rm clinker; fire poked 11 times

as washer nor sawdust scrubber used; fire poked 8 times while running hese figures do not include coal for banking and starting (550 lbs.)

from tar at engine; 26 pounds removed from wet scrubb r; fire pok 25 times.

removed; fire poked 10 times

removed; fire poked 12 times

a tendency to clinker slightly; fire poked 7 times

6 days only; engine valves free from tar at end; fire poked 3 or 4 tim during each day's run of 10 hours.

scrubber; no arch or clinker formed, fire poked 8 times

removed from wet scrubber; the engine valves were dry and sticky a he end; fire poked 7 times

imes

engine valves also were sticking, engine being stopped once; fire poke about every 40 minutes.

s; engine valves clean at the end; fire poked 6 times.

collected; engine valves tarred up; fire poked 27 times

ds of tar collected from wet scrubber; fire poked 17 times

No.

12
13
14
15
16
17
18
27

TABLE IV. SUMMARY RECORD OF BOILER TESTS

No.	Name of colliery	Treatment of coal	Date of trial	Duration of trial (Hours)	Fixed carbon	Volatile matter	Ash	Weight dry coal
1	[illegible] Glace Bay, N.S.	Over 2½" shaking screen and picking belt	31-7-08	10.00	57.6	[illegible]	[illegible]	[illegible]
2	[illegible] Glace Bay, N.S.		3-8-08	[illegible]	59.1	[illegible]	[illegible]	[illegible]
3	[illegible] Glace Bay, N.S.	Over 2½" bar screen and picking table	29-7-08	10.00	55	[illegible]	[illegible]	[illegible]
4	[illegible]	Over 1" screen and picking belt	5-8-08	10.05	[illegible]	[illegible]	[illegible]	2.784
5	[illegible] Glace Bay, N.S.		6-8-08	10.00	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible] Glace Bay, N.S.		7-8-08	10.00	57.3	36.9	[illegible]	2.780
7	[illegible] Sydney Mines, N.S.	Over 2" bars and picking belt	15-8-07	10.05	55.4	37.4	[illegible]	3.080
8	[illegible] Sydney Mines, N.S.		16-8-07	10.00	56.3	40.2	[illegible]	[illegible]
9	[illegible] Sydney Mines, N.S.	Over ¾" screen and picking belt	9-8-07	10.00	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible] Inverness, N.S.	Over ¾" shaking screen and picking belt	20-8-07	10.00	49.6	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	21-8-07	10.00	51.0	[illegible]	[illegible]	[illegible]
12	[illegible] Port Hood, N.S.	Over ¾" shaking screen and picking belt	22-8-07	10.00	48.3	37.1	14.6	[illegible]
13	[illegible] Port Hood, N.S.		23-8-07	10.00	51.2	37.0	[illegible]	[illegible]
14	[illegible] New Glasgow, N.S.	Over ¾" screen and picking belt	10-7-07	10.05	50.6	32.1	[illegible]	[illegible]
15	[illegible] New Glasgow, N.S.		8-7-07	10.00	[illegible]	33.2	[illegible]	[illegible]
16	[illegible] Stellarton, N.S.	Over picking belt only	19-8-07	10.00	55.4	33.3	[illegible]	2.800
17	[illegible] Stellarton, N.S.	Run of mine coal	29-7-07	10.05	55.5	29.8	[illegible]	[illegible]
18	[illegible] Stellarton, N.S.	Resampled No. 1 coal	29-5-08	10.05	57.7	28.5	13.8	2.775
19	[illegible] Stellarton, N.S.	Results of test unreliable on account of error in sampling			56.9	30.8	[illegible]	
20	[illegible] Stellarton, N.S.	Run of mine	5-7-07	10.00	58.1	31.4	[illegible]	2.700
21	[illegible] Westville, N.S.	Over 1" screen and picking belt	12-7-07	10.02	64.8	26.0	[illegible]	2.527
22	[illegible] Westville, N.S.		1-6-08	10.00	64.8	26.0	[illegible]	2.590
23	[illegible] Westville, N.S.	Over 1" screen and picking belt	24-6-07	10.08	60.8	24.7	14.5	2.564
24	[illegible] Westville, N.S.		3-7-07	10.00	60.8	24.7	14	2.807
25	[illegible] Westville, N.S.		26-6-07	10.00	63.1	[illegible]	[illegible]	2.547
26	[illegible] Springhill, N.S.	Over ¾" screen and picking belt	22-7-07	10.00	58.5	[illegible]	[illegible]	[illegible]
27	[illegible] Springhill, N.S.		26-7-07	10.00	59.8	[illegible]	[illegible]	[illegible]
28	[illegible] Springhill, N.S.	Over ¾" screen and picking belt	5-8-07	10.15	55.0	[illegible]	[illegible]	3.325
29	[illegible] Springhill, N.S.		7-8-07	10.00	57.0	34.7	8	2.872
30	[illegible] Chignecto, N.S.	Hand picked sample	21-6-07	10.00	45.7	41.0	[illegible]	[illegible]
31	[illegible] Chignecto, N.S.		24-7-07	10.00	[illegible]	[illegible]	[illegible]	3.166
32	[illegible] River Hebert, N.S.	Over ¾" screen and picking belt	16-7-07	10.10	48.8	[illegible]	[illegible]	[illegible]
33	[illegible] River Hebert, N.S.		15-7-07	10.00	51.7	37.3	[illegible]	[illegible]
34	[illegible]	Over ¾" screen and picking belt	12-8-07	10.00	44.8	[illegible]	18.6	3.671
35	[illegible]		13-8-07	10.05	51.6	[illegible]	10	3.222
36	[illegible] Minto, N.B.	Over ¾" screen, no picking belt	28-6-07	[illegible]	53.1	32.2	[illegible]	[illegible]
37	[illegible] Minto, N.B.		2-7-07	10.05	56.6	34.0	9.4	2.888

MARY RECORD OF BOILER TESTS.

		2	3	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
[illegible]	Per Hour [illegible]	Ev. Per [illegible] Per Sq. Ft. of H. S.	Steam Press. Gauge	Barometer	Temp. Feed Water	Force of Draft bet. Ash Pit and Damper	Moisture in Steam	Boiler Horse-power	Per Lb. Coal as Fired: Water Apparently Evap.	Per Lb. Coal as Fired: Equivalent Evap. From and at 212° F.	Per Lb. Dry Coal: Equivalent Evap. From and at 212° F.	Per Lb. Comb.	Cal. Value Coal Fired Per Lb.	Cal. Value Calorimeter Dry Coal Per Lb.	Boiler Efficiency based on Comb. Consumed	Boiler Efficiency based on Dry Coal	Dry Flue Gas Per Lb. Dry Coal	Heat of Fuel in Dry Flue Gas	Temp. of Escaping Flue Gas at Damper	Treatment of Coal When Burning	General Remarks	
[illegible]	[illegible]	[illegible]	Lbs. per Sq. Inch	[illegible]	[illegible]	Ins. Water	[illegible]		Lbs.	Lbs.	Lbs.	Lbs.	B.T.U.	B.T.U.	%	%	Lbs.	%	[illegible]			
1 [illegible]	2,092	3	118.4	29.[illegible]	7[illegible]	0.29	0.6	60.5	5.99	7.08	7.[illegible]	7.8[illegible]	13,490	14,860	51.4	50.8	17.[illegible]	15.[illegible]	616	Air admitted over fire	Bluish plastic clinker easily removed, much flame and smoke	1
[illegible]	2,122	[illegible]	111.[illegible]	29.85	72.4	0.30	0.6	61.5	6.20	7.33	7.8[illegible]	7.98	13,670	14,310	52.4	51.8	19.0	16.9	617	Air admitted over fire, steam under bars to prevent clinker sticking	Clinker troublesome until steam used, much flame and smoke, cakes badly.	2
1 8[illegible]	2,122	3.12	117.7	29.88	72.4	0.23	0.6	61.6	6.09	7.21	7.[illegible]	7.93	13,780	14,000	51.4	50.6	15.6	15.2	600	Air over fire, steam under bars.	Clinker in thin hard cakes, adheres to bars, dense smoke	3
[illegible]	2,099	3.30	117.9	29.48	72.7	0.27	0.6	61.1	6.26	7.40	7.[illegible]	8.22	13,620	14,010	53.3	52.4	18.2	15.1	600	Air over fire, steam under bars	Clinker hard and adheres to bars, dense smoke, cakes a little	4
1 801	2,158	3.[illegible]	118.4	29.57	72.6	0.26	0.6	62.5	5.83	6.90	7.[illegible]	8.17	12,750	13,120	53.4	52.2	18.2	17.3	608	Fire about 4" thick	Clinker hard and small, easily removed, shaking grate advantageous, dense smoke	5
1 [illegible]64	2,095	3.2[illegible]	116.6	29.57	73.0	0.27	0.6	60.7	6.07	7.17	7.[illegible]	8.06	13,200	13,800	52.9	52.2	19.3	15.2	541	Fire about 2" thick	Large slabs of clinker, not adherent, dense smoke	6
1 88[illegible]	2,12[illegible]	3.[illegible]	[illegible]	30.05	71.0	0.42	1.0	61.7	5.74	6.74	[illegible]	7.71	13,450	13,770	50.2	48.[illegible]	18.4	13.0	490	Air over fire, steam under bars	Clinker hard and difficult to remove, coal cakes, coal burns with much flame	7
1 88[illegible]	2,238	3.[illegible]	[illegible]	29.85	72.2	0.20	1.0	64.9	5.93	7.01	7.[illegible]	7.70	14,010	14,490	49.6	48.4	20.4	16.4	572	Air over fire, steam under bars	Clinker thin and removed without difficulty	8
1 801	2,2[illegible]	[illegible]	106.9	29.84	71.[illegible]	0.20	1.0	62.1	5.74	6.77	7.[illegible]	7.75	13,110	13,680	51.0	50.0	19.2	16.2	577	Air admitted over fire	Clinker thin and hard, coal cakes and burns with long flame	9
1 804	2,251	[illegible]	111.8	29.7[illegible]	71.2	0.25	1.0	65.3	4.62	5.46	5.[illegible]	6.76	11,200	12,150	46.9	47.7	15.6	14.2	549	Air admitted over fire, steam under bars, fire sliced 4 times	Clinker thin, hard, and adherent, coal cakes and burns with much flame	10
1 871	2,226	[illegible]	114.8	29.86	70.1	0.17	1.0	64.5	4.79	5.67	6.[illegible]	6.93	11,620	12,800	48.9	47.0	15.7	14.2	565	Air admitted over fire, steam under bars	Clinker removed without difficulty, coal cakes and burns with much flame	11
1 790	2,081	3.[illegible]	110.6	29.91	70.0	0.24	1.0	60.4	4.90	5.87	5.[illegible]	6.98	11,380	11,770	48.9	48.2	17.0	14.6	486	Air admitted over fire, steam under bars, fire sliced 3 times	Clinker compact and blue, hanging from bars, coal cakes and burns with much flame	12
1 721	2,057	3.[illegible]	112.5	29.87	70.6	0.20	1.0	59.5	4.97	5.85	6.[illegible]	7.10	11,[illegible]60	12,550	4[illegible]	47.7	19.0	16.5	54[illegible]	Air admitted over fire, steam under bars	Clinker friable, removed without difficulty, coal cakes and burns with much flame	13
1 7[illegible]	2,110	[illegible]	115.1	29.62	69.9	0.24	1.0	62.0	5.13	6.04	6.[illegible]	7.84	11,980	[illegible]20	52.0	50.0	15.9	12.7	486	Air admitted over fire throughout trial	Clinker thick, viscous, porous, and friable, contained many pieces of burnt stone	14
1 77[illegible]	2,114	[illegible]	110.6	29.58	69.9	0.21	1.0	61.3	5.38	6.24	6.[illegible]	7.60	[illegible]2,280	12,700	50.2	49.2	15.2	11.7	499	Air admitted over fire	Clinker porous, viscous, and friable when cold, whitish in colour, coal burns with much flame	15
1 792	2,137	[illegible]	111.9	29.90	7[illegible]	0.28	1.0	61.9	6.14	7.24	7.[illegible]	8.40	12,990	13,230	55.0	53.9	20.2	15.7	514	Air admitted over fire	Clinker thick and viscous, burns with much flame, coal cakes	16
1 682	1,998	[illegible]	109.7	29.80	[illegible]	0.24	1.0	57.9	6.20	7.38	7.[illegible]	9.10	12,330	12,580	59.5	57.9			440	Air over fire for 1 hour, fire sliced [illegible] times	Clinker thick, porous, friable, removed without difficulty, coal cakes and burns with much flame and smoke	17
1 730	2,080	3.[illegible]	117.0	29.60	58.0	0.20	0.5	60.3	6.18	7.38	7.[illegible]	9.00	12,210	12,460	60.1	58.4	20.0	15.5	493	Air admitted a little over fire	Clinker thick, porous, friable, removed without difficulty, coal cakes and burns with much flame and smoke	18
														13,050								19
1 780	2,113		111.1	[illegible]	69.[illegible]	0.23	3.0	61.4	6.47	7.49	7.6[illegible]	8.80	12,880	14,180	57.7	56.3	17.9	14.6	547		Clinker porous, friable, and easily removed, coal does not appear to cake	20
1 843	2,19[illegible]	[illegible]	114.3	29.[illegible]	7[illegible]	0.25	1.0	63.5	7.68	8.55	8.6[illegible]	9.68	13,640	13,860	61.3	60.6	17.8	11.8	462	Air admitted over fire	Clinker thick, whitish, and difficult to break up, coal does not cake	21
1 [illegible]90	2,161	3.[illegible]	114.4	29.68	56.5	0.21	0.7	62.7	6.86	8.25	8.[illegible]	9.32	13,600	13,800	59.0	58.3	21.4	16.6	501		No difficulties, clinker hard and friable, shaking grate advantageous, light smoke	22
1 660	1,9[illegible]		111.1	[illegible]72	[illegible]	0.13	3.0	57.4	6.57	7.69	7.[illegible]	9.28	12,820	12,960	59.2	58.0			437	Fire sliced frequently, cleaned twice	Clinker thick and viscous, friable when cold; No. 1 boiler cold	23
1 [illegible]94	[illegible]		[illegible]6.2	29.82	67	0.25	4.0	62.0	6.50	7.53	7.6[illegible]	9.26	12,810	12,960	59.0	56.8	30.2	22.7	494	Fire sliced 5 times, cleaned twice	Clinker thick and friable, No. 1 boiler working	24
1 723	[illegible]	[illegible]	112.5	29.12	67.0	0.17	2.0	60.6	6.77	8.07	8.2	9.45	13,320	13,550	59.7	5[illegible].6			479	Fire sliced 3 times, cleaned once	Clinker whitish, spongy, and very friable, coal formed large cakes of coke	25
1 801	2,137	[illegible]	116.6	29.58	73.7	0.22	1.0	61.9	5.65	6.63	6.7[illegible]	7.65	13,120	13,370	50.1	49.0	20.[illegible]	15.2	462	Fire sliced 5 times, air admitted over fire	Clinker viscous and adherent	26
1 826	2,168	[illegible]	116.0	29.23	73.2	0.28	1.0	62.9	6.26	7.36	7.6	8.30	13,330	13,860	53.7	53.1			476	Air admitted over fire	Clinker thick and viscous, removed in large slabs, coal caked readily	27
1 7[illegible]	2,070	3.[illegible]	112.0	29.85	70.0	0.[illegible]	1.0	60.0	5.25	6.18	6.3	7.59	12,710	13,000	49.9	46.9	2[illegible]	18.9	505	Air admitted over fire	Clinker thick and viscous, coal caked and burns with much flame and smoke	28
1 804	2,145	3.[illegible]	115.2	29.68	71.0	0.22	1.0	62.2	6.10	7.20	7.4[illegible]	8.35	13,110	13,570	54.5	53.4	21.0	15.6	511	Air admitted over fire.	Clinker viscous	29
1 771	2,124	3.[illegible]	109.5	29.88	64.5	0.19	4.0	61.7	5.01	5.82	6.0	7.26	11,790	12,150	50.1	47.9	25.8	17.1	429	Fire sliced 4 times, cleaned 4 times, steam blown under grate	Clinker thin, vitreous, and adherent	30
1 779	2,111	3.[illegible]	114.9	29.56	73.9	0.39	1.0	61.1	5.37	6.31	6.6[illegible]	7.50	12,210	12,890	51.1	50.0	18.4	13.4	474	Steam under bars	Clinker formed a thin hard sheet over bars, conditions improved with use of steam	31
1 728	2,052	3.2[illegible]	109.7	29.75	72.2	0.46	1.0	59.4	4.7[illegible]	5.61	5.78	6.98	11,500	11,830	48.1	47.1	14.8	[illegible]	539.5	Fire sliced 6 times, steam under bars	Clinker fairly thick and adhering to bars	32
1 741	2,068	3.24	112.0	29.82	71.6	0.41	1.0	59.9	5.18	6.09	6.3[illegible]	7.26	12,160	12,600	49.5	48.5	16.5	13.3	522	Steam under bars, fire sliced 4 times, cleaned twice	Clinker thin, hard, and adherent	33
1 811	2,141	3.[illegible]5	108.8	29.48	71.4	0.25	1.0	62.1	4.82	5.66	5.84	7.44	11,250	11,590	50.6	48.7	17.1	17.0	575	Air admitted over fire, steam blown under bars	Clinker hard and porous, coal cakes slightly	34
1 747	2,[illegible]72	3.[illegible]	[illegible]	29.5[illegible]	7[illegible]	0.30	1.0	60.0	5.28	6.22	6.47	7.37	12,250	12,740	50.1	48.9	18.8	14.5	499	Air admitted over fire	Clinker thin, hard, removed with difficulty; coal cakes readily and burns with much flame	35
1 555	1,860	2.91	112.4	29.71	66.0	0.26	3.0	54.0	5.18	6.03	6.0[illegible]	7.34	12,800	12,890	47.1	45.5	18.2	13.0	478	Steam under bars	Clinker blue, vitreous, and adherent	36
1 664	1,983	3.[illegible]	114.6	29.55	67.7	0.41	4.0	57.5	5.87	6.80	6.90	7.84	13,590	13,820	49.5	48.3	25.8	16.0	447		Clinker hard and blue, coal cakes readily.	37

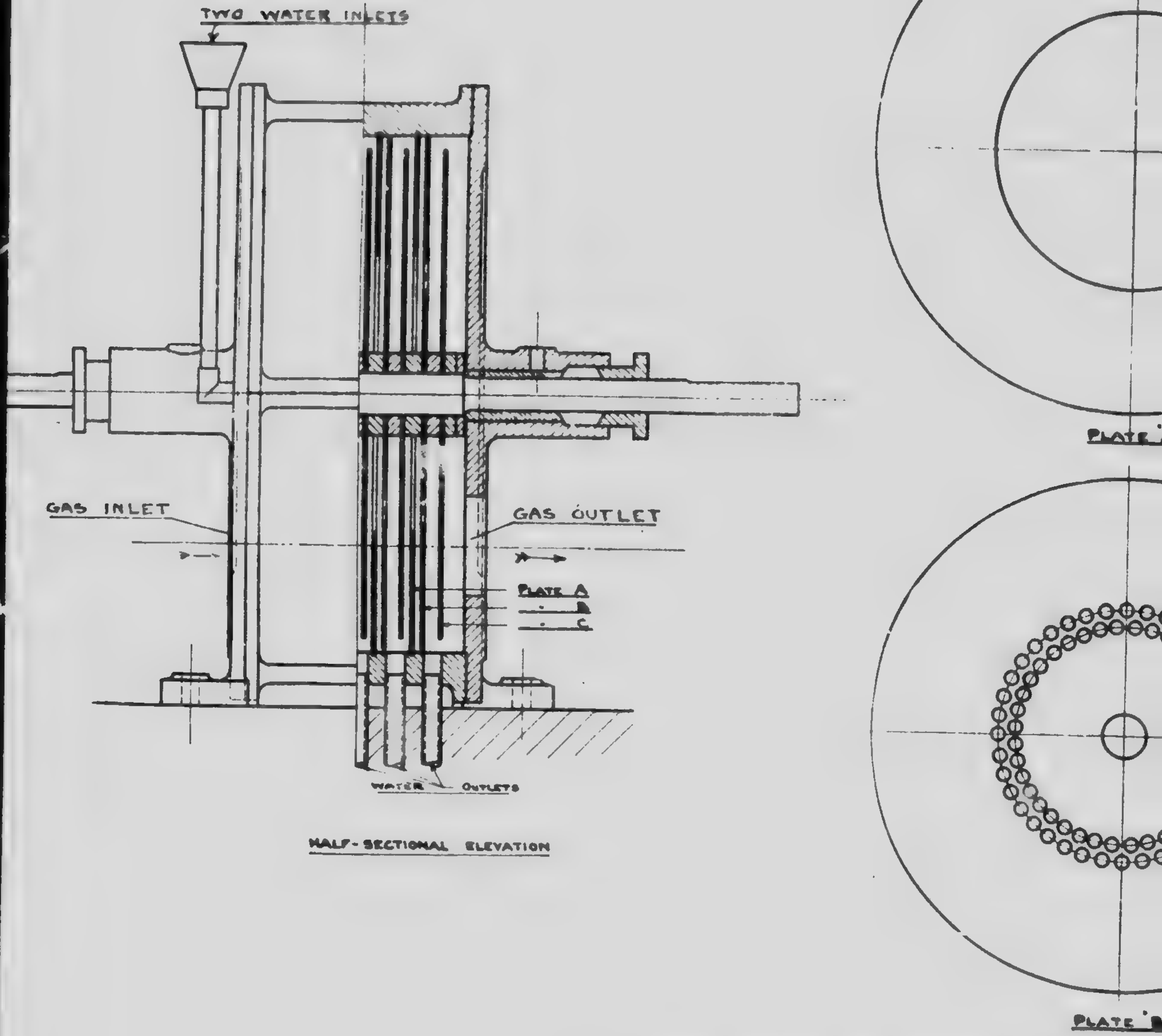


Fig. 47. Section through gas washer Department of Mechanical Eng

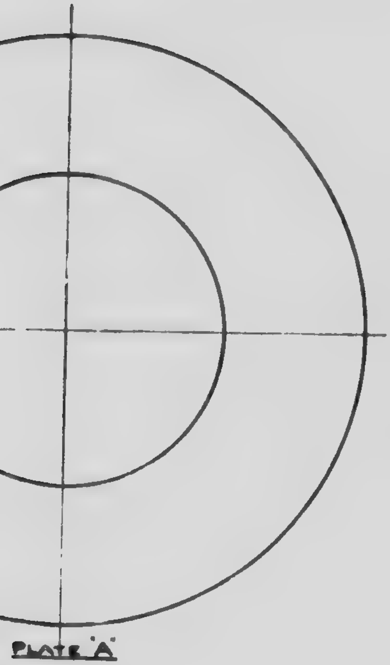


PLATE 'A'

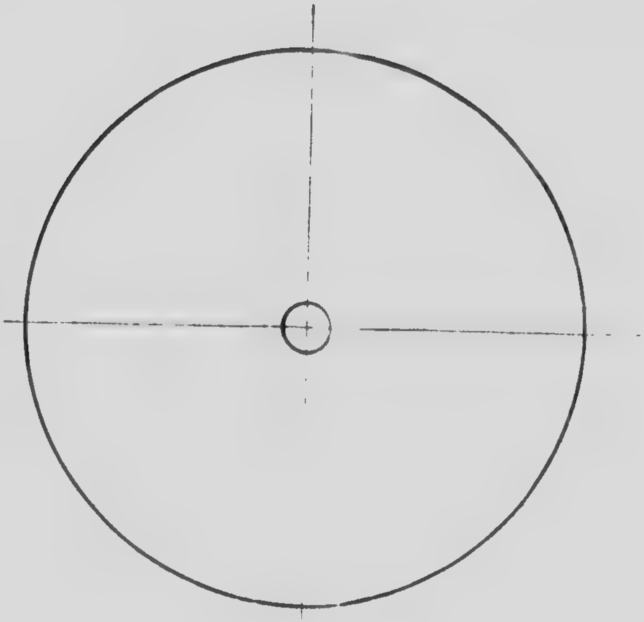


PLATE 'C'

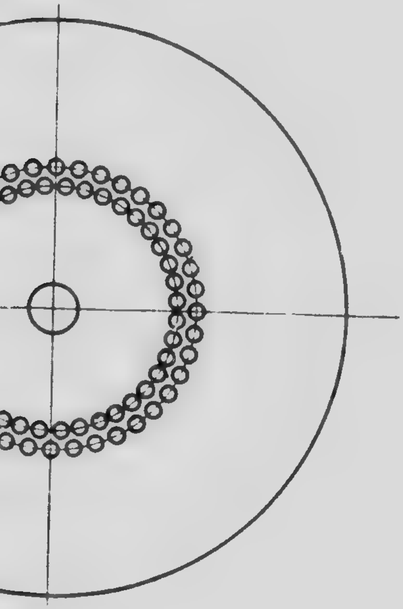


PLATE 'B'

anical Engineering, McGill University.

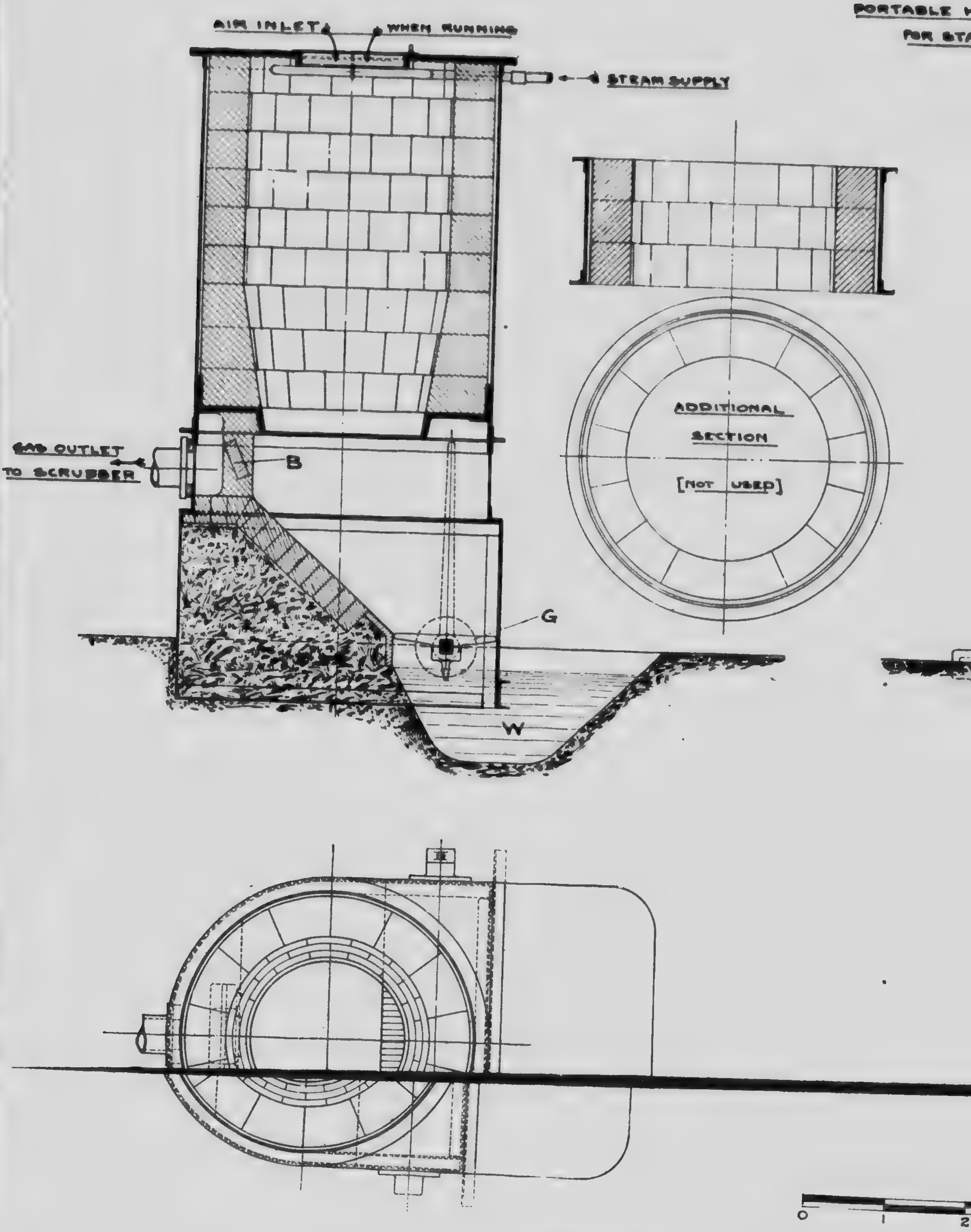
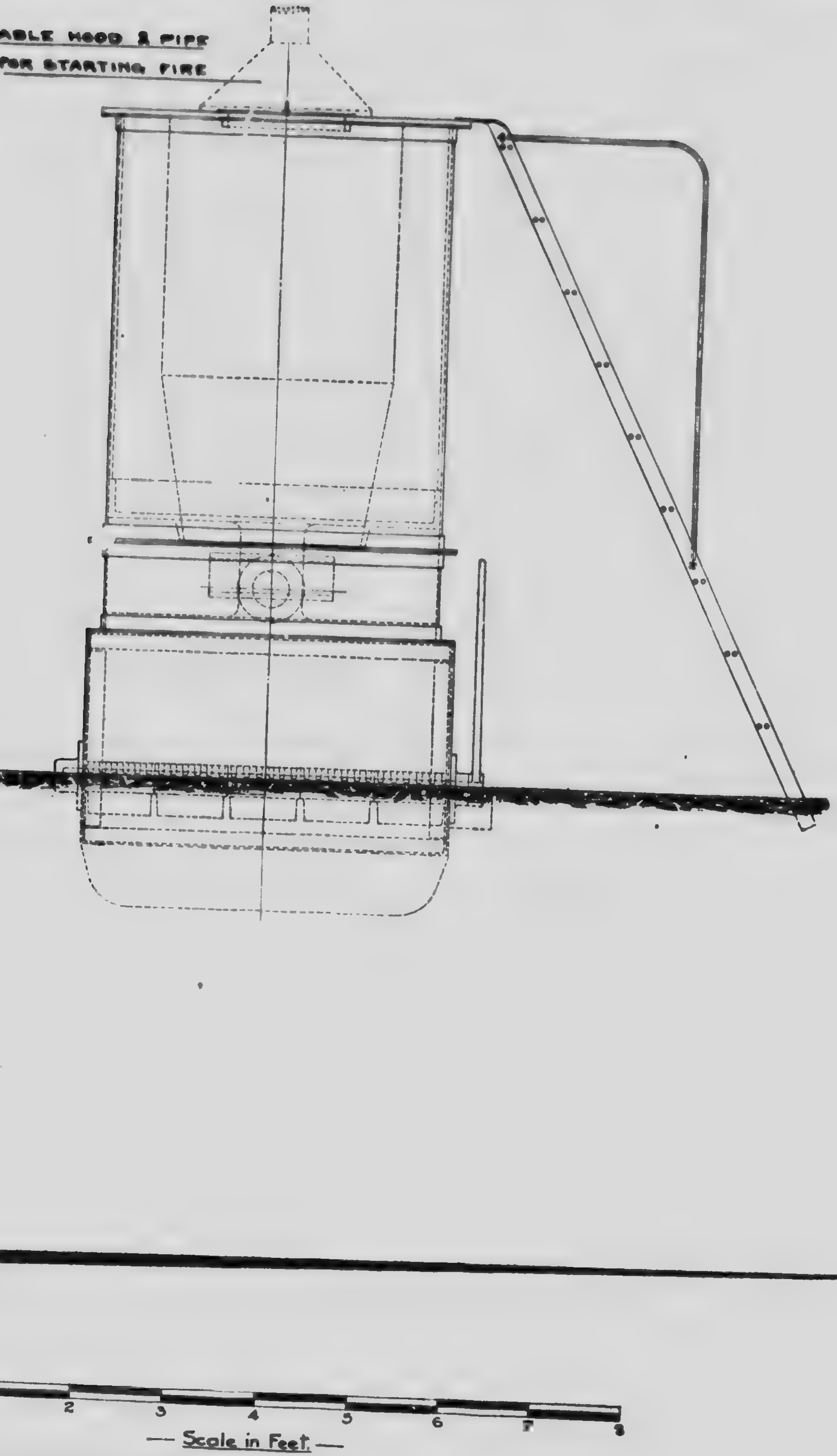


Fig. 45. Down-draft producer, No. 4. Department of Mechanical Engineerin



Engineering, McGill University.

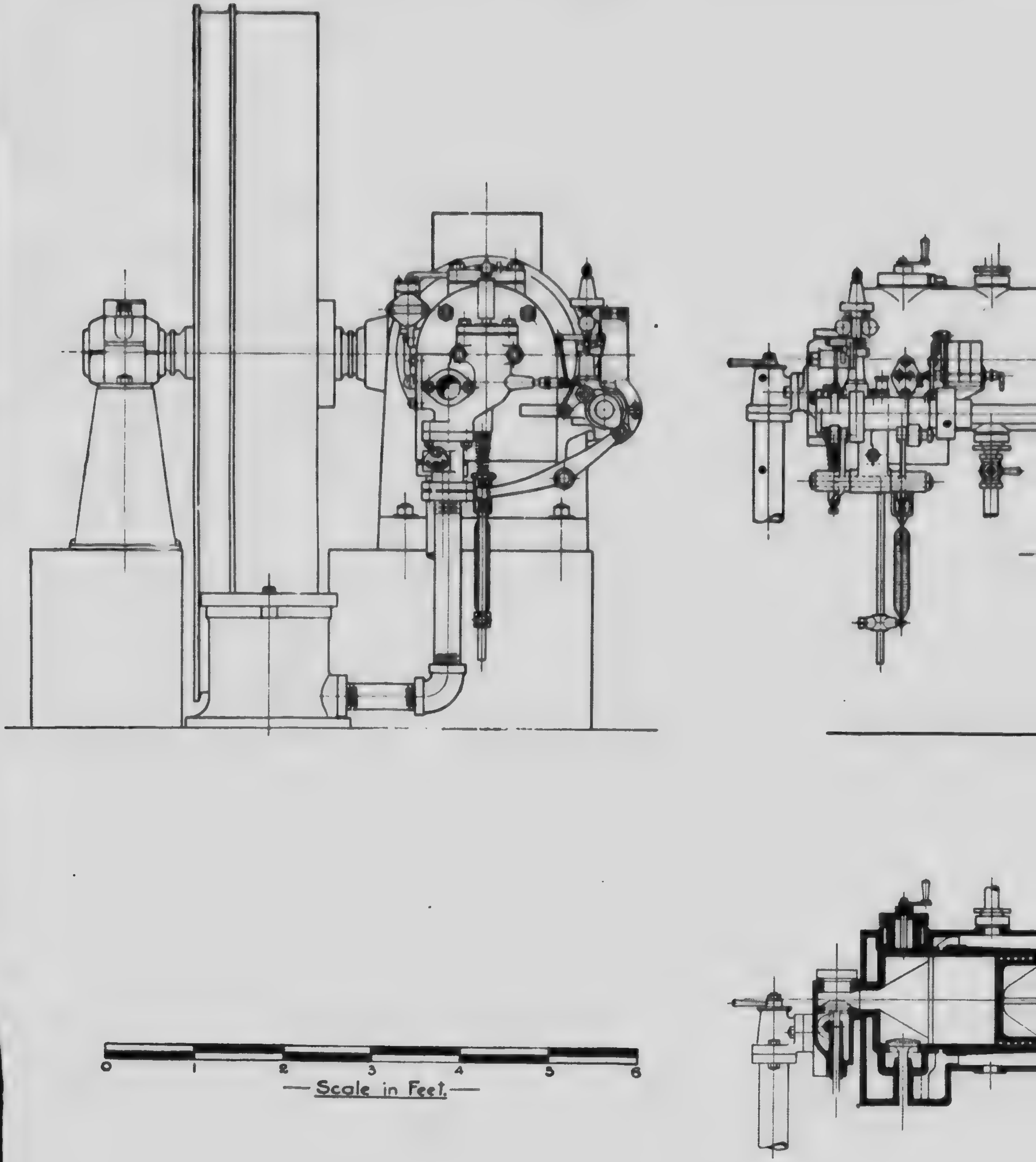
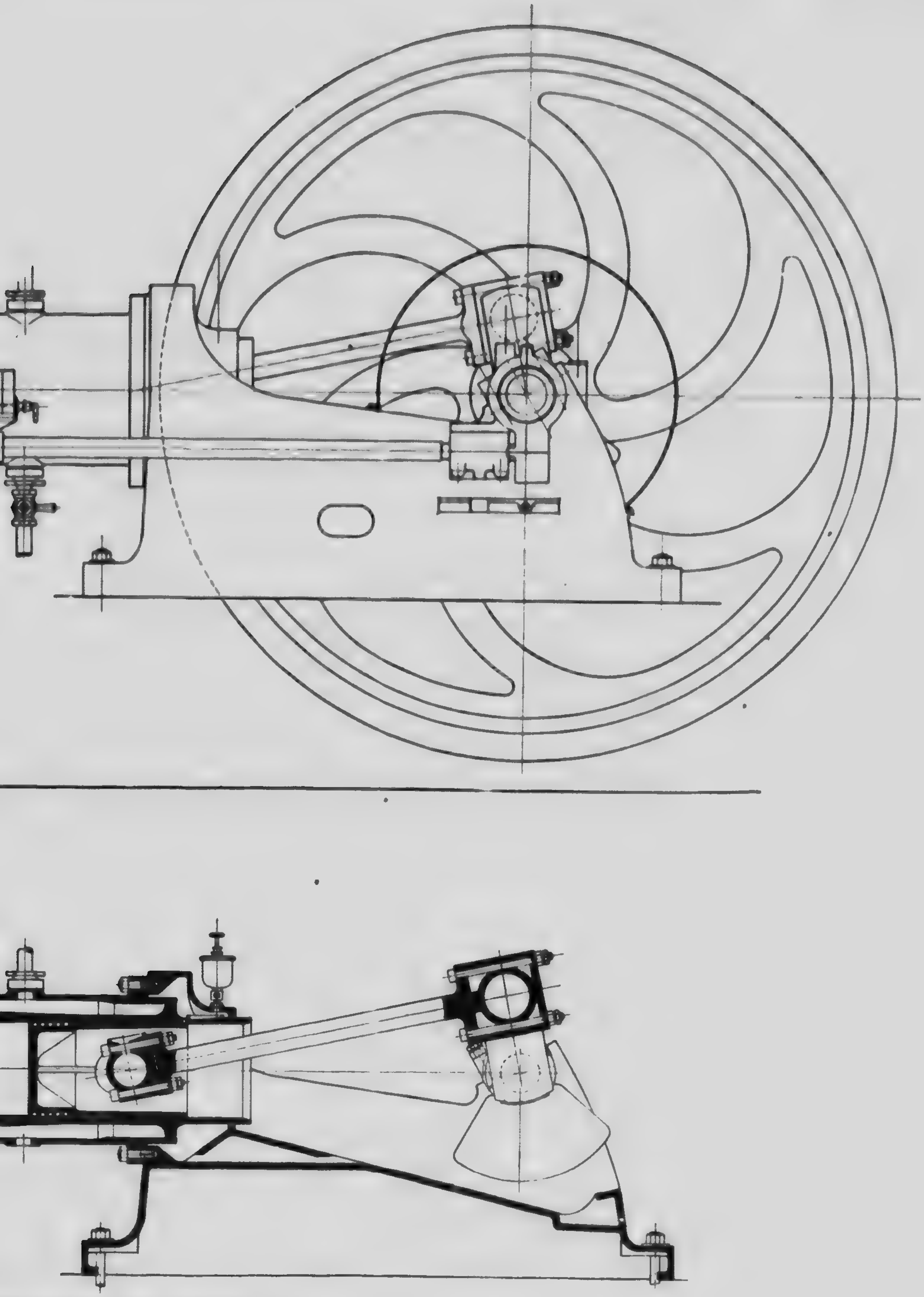


Fig. 46. Forty horse-power gas engine. Department of Mechanical



Mechanical Engineering, McGill University.

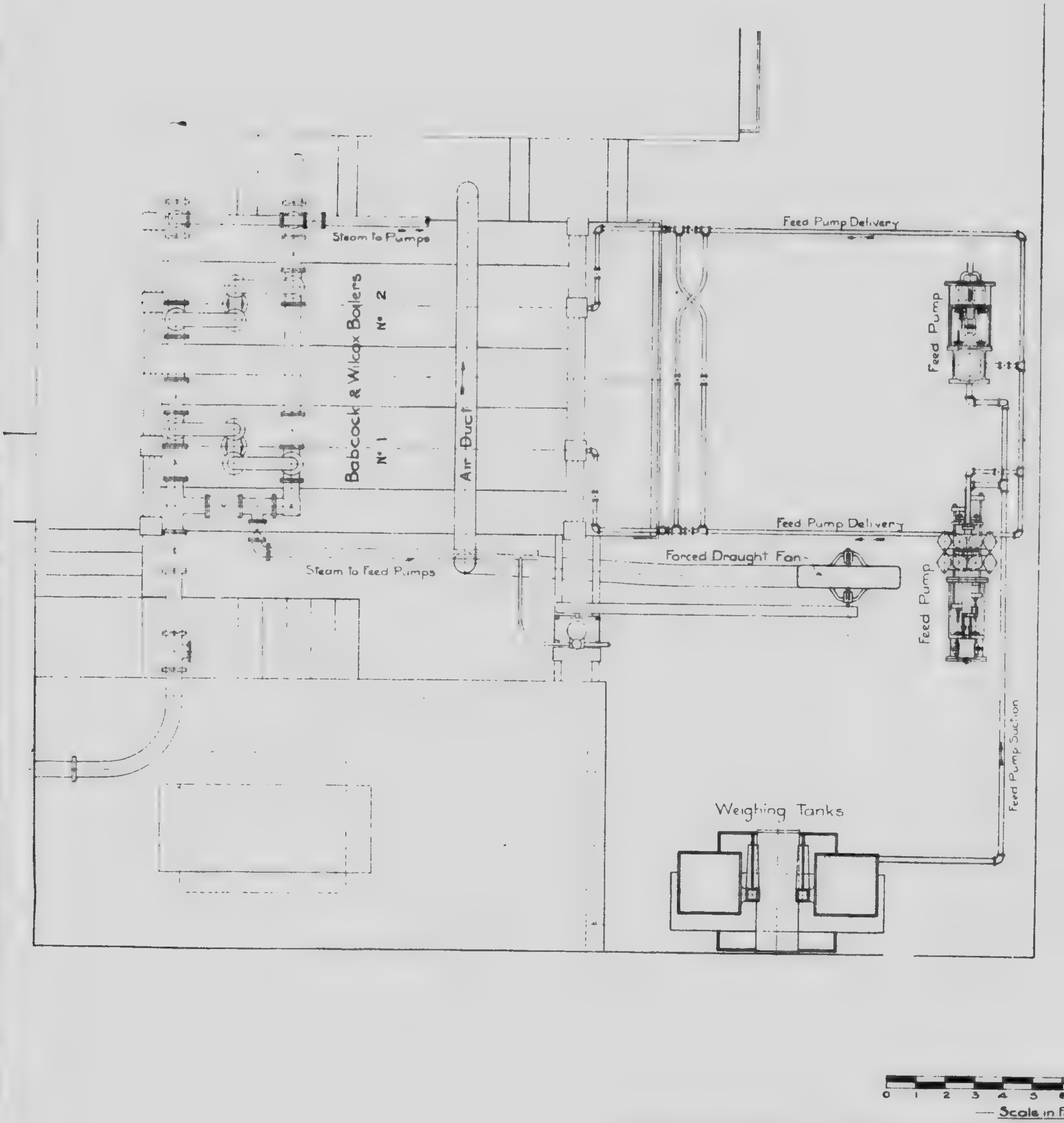
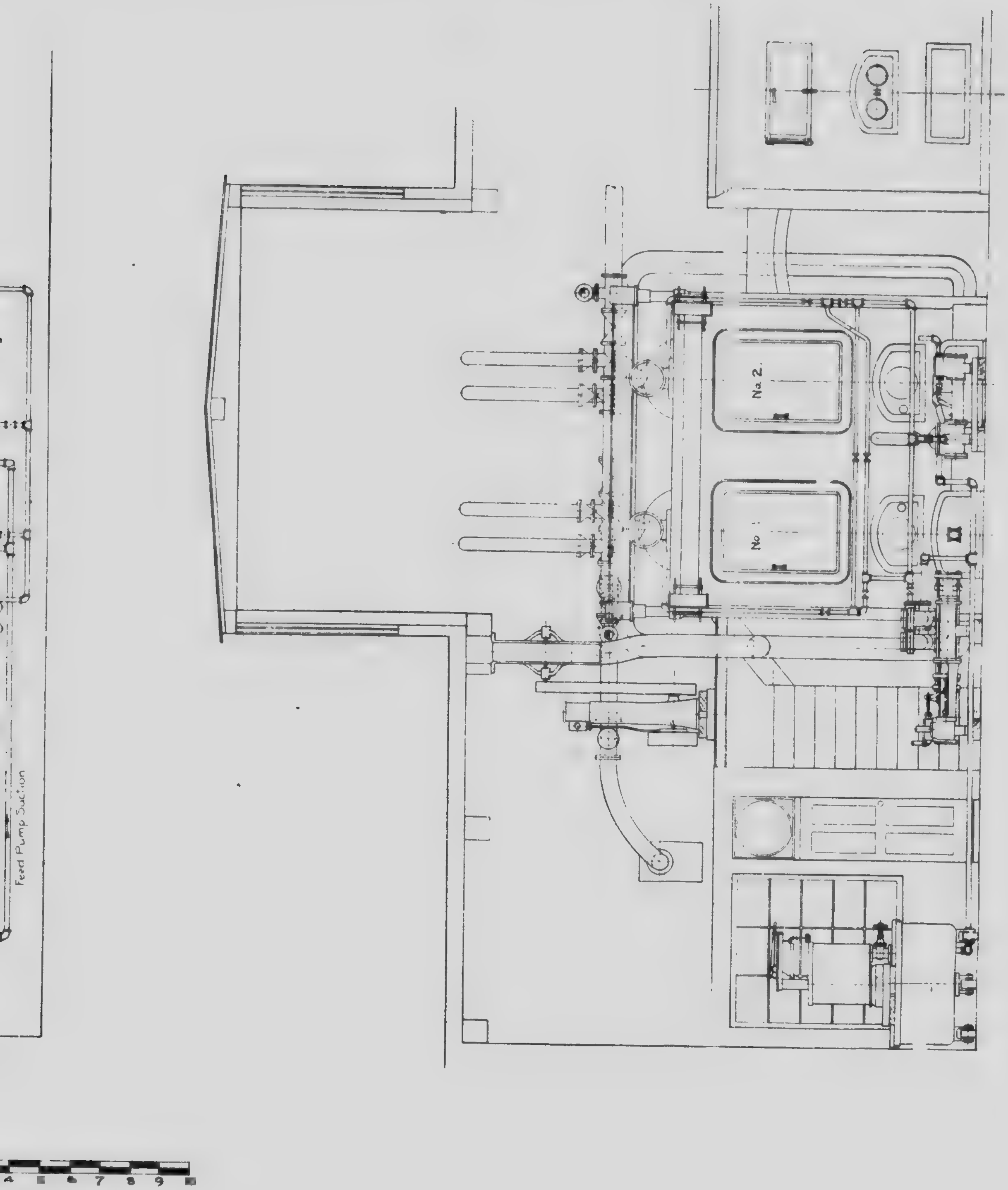


Fig. 34. General arrangement of experimental boiler plant. Departmen



Department of Mechanical Engineering, McGill University

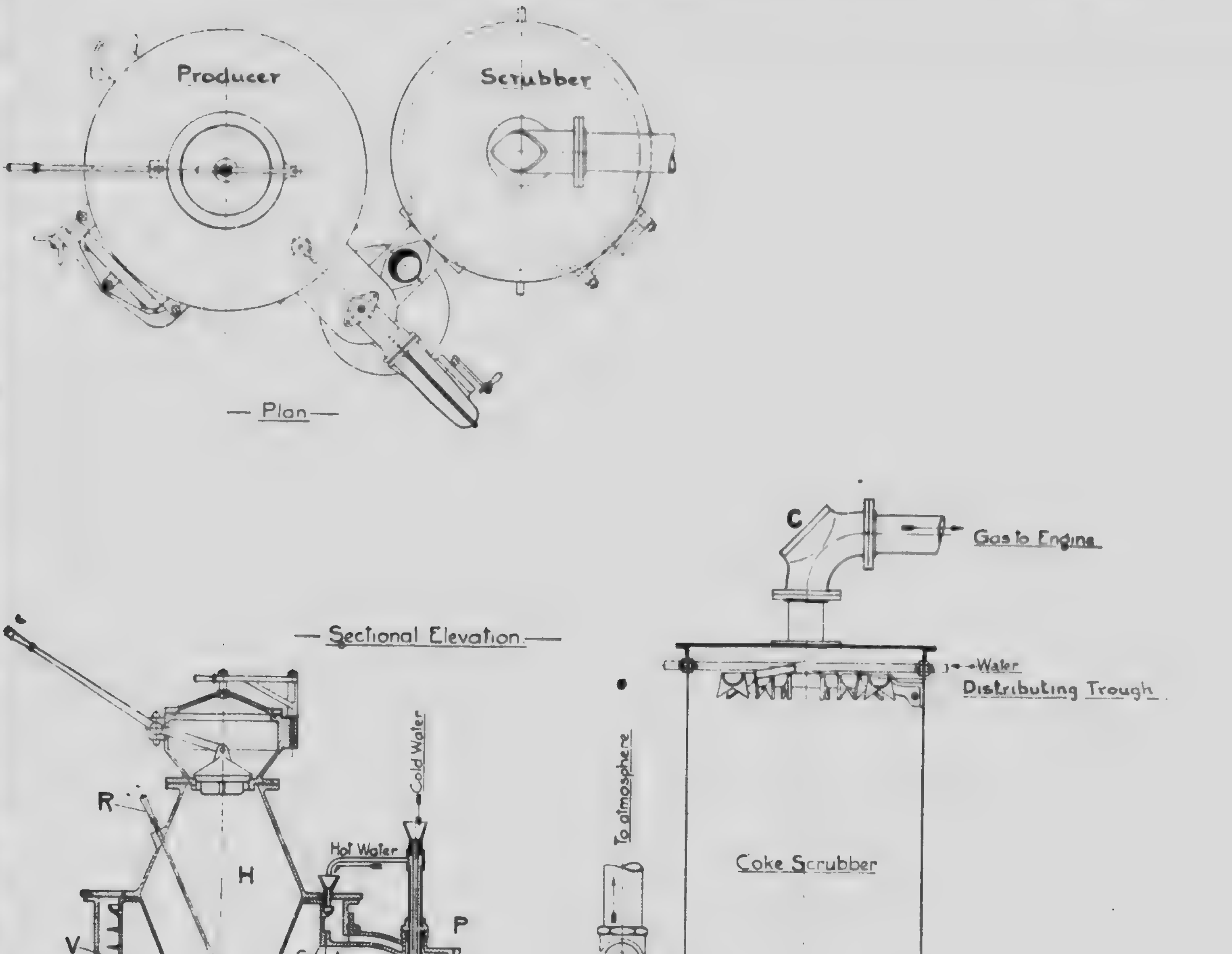
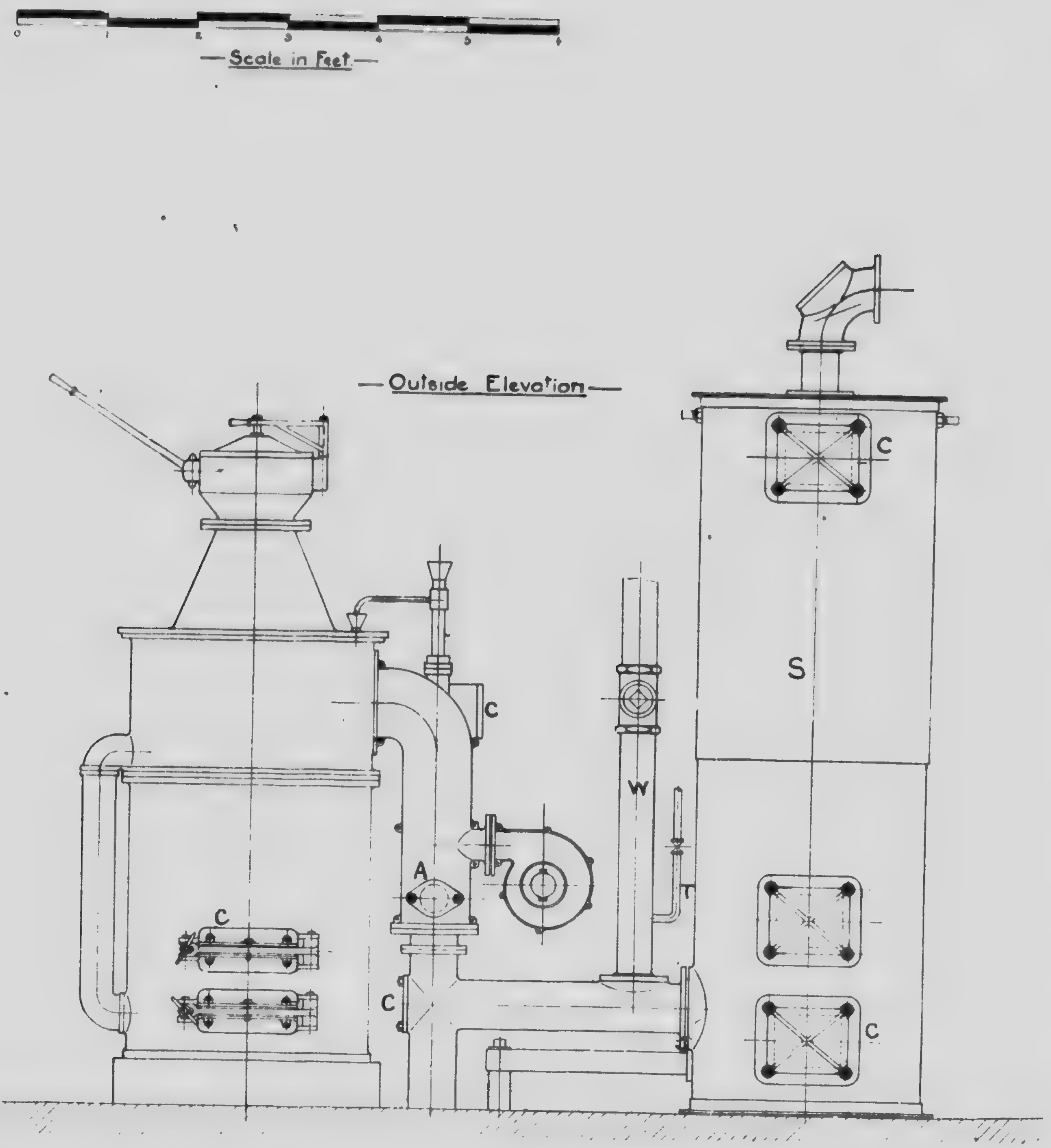


Fig. 44. Suction producer (No. 1). Department of Mec



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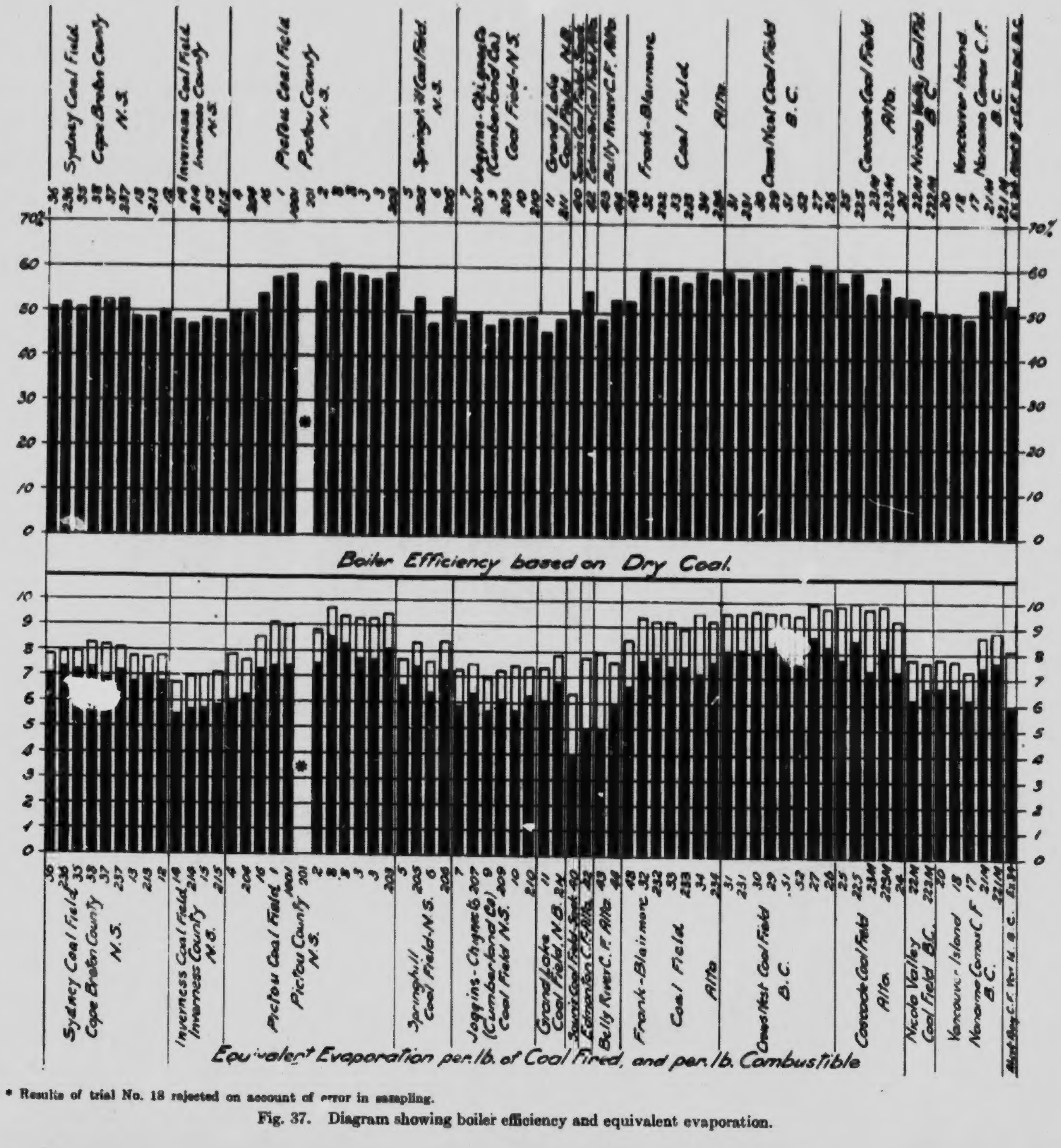

* Results of trial No. 18 rejected on account of error in sampling.

Fig. 37. Diagram showing boiler efficiency and equivalent evaporation.

T

Date, July 31, 1908.

Boiler gauge subtr
Calorimeter gauge
Calorimeter therm.
Barometer at start

Time	Gross	Tare	Water Discharged
8.40	......	......	......
8.55	......	......	......
9.10	539	131	408
9.25	539	132	407
9.40	542	128	414
9.55	537	129	408
10.10	537·5	128	409·5
10.25	542	128	414
10 40	539	129	410
	540	127·5	412·5
10.55	539	127·5	411·5
11.10	540	127·5	412·5
11.25	538·5	128	410·5
11.40	541	128	413
11.55	540	127	413
12.10	537·5	128	409·5
	539	129	410
12.25	541	128	413
12.40	539	127·5	411·5
12.55	538	127	411
1.10	539	127	412
1.25	541	128	413
1.40	539	128·5	410·5
1.55	538·5	127·5	411
	550	130	420
2.10	538	133	405
2.25	538	128·5	409·5
2.40	538	129	409
2.55	537	127·5	409·5
3.10	538	128	410
3.25	538	127	411
3.40	537·5	128·5	409
3.55	540	130	410
4.10	539·5	128	411·5
4.25	538	128	410
4.40	540	129	411
4.55	540	128	412
5.10	540·5	128	412·5
5.25	541	130	411
5.40	540	129	411
5.55	537	127·5	409·5
6.10	540	131	409
6.25	541	133	408
6.40	537	129	408

TABLE II

TRIALS OF No. 2. BABCOCK AND WILCOX BOILER WITH No. 36 COAL.

Date, July 31, 1908.

Trial Number, G. C. T. 58.

OBSERVATIONS OF FEED WATER PRESSURES, AND TEMPERATURES.

Boiler gauge subtract 2 lbs. from reading.
Calorimeter gauge correct.
Calorimeter therm. correct. No. 65100, 0°-400° F.
Barometer at start 29·64, at finish 29·54.

Corrections *not* allowed for on sheets.
Feed therms. Hicks Nos. 15706
and 15701 subt. 0·5° F.
Air therm. subt. 1°F.

Time	Gross	Tare	Water Discharged	Lower Tank Rdg.	Gauge Glass Rdg.	Lbs. Evaporation		Boiler Press. Lbs. per Sq. In.	Cal. Press. Lbs. per Sq. In.	Cal. Temp. °F.	Draught in Ins. Water			Damper Opening Ins.	Boiler Room Temp. °F.	Feed Temp. °F.	Flue Gas Temp. °F.
						In Interval	Per Min.				At Damper	Above Grate	Below Grate				
8.40	......	......	......	1850	310	....	......	118	15·2	290	0·24	0·16	0·02	24″	90	72·5	570
8.55	......	......	......	1280	360	520	34·7	114	14·5	290	0·24	0·16	0·02	24″	90	72·5	560
9.10	539	131	408	1340	330	378	25·2	124	16·2	293	0·26	0·20	0·02	24″	90	73·0	575
9.25	539	132	407	1170	370	537	35·8	·115	15·0	290	0·27	0·18	0·02	24″	90	73·0	570
9.40	542	128	414	1180	320	454	30·3	124	16·0	294	0·26	0·16	0·02	24″	91	73·0	620
9.55	537	129	408	1030	440	438	29·2	120	15·4	293	0·26	0·16	0·02	24″	91	73·0	580
10.10	537·5	128	409·5	1100	250	529·5	35·3	124	16·1	294	0·26	0·20	0·02	24″	91	73·5	620
10.25	542	128	414	950	320	494	32·9	125	16·4	294	0·27	0·18	0·02	24″	91	73·5	630
10.40	539 540	129 127·5	410 412·5	1160	360	572·5	38·2	122	16·0	294	0·27	0·18	0·02	24″	91	73·5	640
10.55	539	127·5	411·5	1210	290	431·5	28·8	123	16·1	294	0·28	0·18	0·02	24″	92	73·5	625
11.10	540	127·5	412·5	1020	420	472·5	31·5	120	15·3	292	0·28	0·18	0·02	24″	91	73·5	610
11.25	538·5	128	410·5	1000	370	480·5	32·1	124	16·3	293	0·28	0·18	0·02	24″	92	73·5	580
11.40	541	128	413	1020	350	413	27·5	124	16·1	294	0·28	0·18	0·02	24″	92	73·5	590
11.55	540	127	413	940	430	413	27·5	122	15·8	293	0·28	0·18	0·02	24″	92	73·5	585
12.10	537·5 539	128 129	409·5 410	1380	340	469·5	31·3	119	16·3	293	0·28	0·18	0·02	24″	92	73·5	635
12.25	541	128	413	1280	330	523	34·9	124	16·2	294	0·28	0·18	0·02	24″	91	73·5	600
12.40	539	127·5	411·5	1090	440	491·5	32·8	125	16·4	294	0·28	0·18	0·02	24″	91	73·5	640
12.55	538	127	411	1100	420	421	28·1	123	16·2	294	0·28	0·18	0·02	24″	91	73·5	600
1.10	539	127	412	1070	390	472	31·5	125	16·4	294	0·28	0·18	0·02	24″	92	74·0	700
1.25	541	128	413	1050	340	483	32·2	121	15·6	294	0·28	0·18	0·02	24″	91	73·5	620
1.40	539	128·5	410·5	980	410	410·5	27·4	125	16·4	294	0·28	0·18	0·02	24″	91	73·5	610
1.55	538·5 550	127·5 130	411 420	1350	350	521	34·7	123	16·2	294	0·28	0·18	0·02	24″	91	73·5	620
2.10	538	133	405	1260	460	385	25·7	125	16·4	294	0·26	0·18	0·02	24″	92	73·5	560
2.25	538	128·5	409·5	1340	350	439·5	29·3	122	15·6	294	0·26	0·18	0·02	24″	96	74·0	570
2.40	538	129	409	1280	370	449	29·9	116	15·0	292	0·26	0·18	0·02	24″	92	74·0	660
2.55	537	127·5	409·5	1240	370	449·5	30·0	117	15·2	290	0·26	0·18	0·02	24″	92	74·0	630
3.10	538	128	410	1300	340	380	25·3	113	14·2	290	0·26	0·18	0·02	24″	92	74·5	600
3.25	538	127	411	1290	390	371	24·7	117	15·2	290	0·26	0·18	0·02	24″	92	74·5	630
3.40	537·5	128·5	409	1330	460	299	19·9	125	16·4	294	0·30	0·20	0·02	24″	93	75·0	780
3.55	540	130	410	1300	370	530	35·3	118	15·3	291	0·30	0·20	0·02	24″	92	75·0	720
4.10	539·5	128	411·5	1230	360	491·5	32·8	120	15·8	294	0·30	0·20	0·02	24″	92	75·0	710
4.25	538	128	410	1180	360	460	30·7	124	16·1	294	0·30	0·20	0·02	24″	92	75·0	650
4.40	540	129	411	1100	340	511	34·1	125	16·4	294	0·28	0·20	0·02	24″	94	75·0	640
4.55	540	128	412	1060	380	412	27·5	125	16·4	293	0·28	0·20	0·02	24″	92	75·0	640
5.10	540·5	128	412·5	1060	360	432·5	28·9	123	16·0	292	0·28	0·20	0·02	24″	90	75·0	610
5.25	541	130	411	1030	420	381	25·4	120	15·6	290	0·28	0·20	0·02	24″	90	75·0	580
5.40	540	129	411	1210	320	331	22·1	95	11·0	286	0·28	0·20	0·02	24″	98	75·0	540
5.55	537	127·5	409·5	1210	380	349·5	23·3	100	12·3	281	0·26	0·18	0·02	18″ at 5·55	90	75·0	520
6.10	540	131	409	1340	380	279	18·6	119	15·4	290	0·26	0·18	0·02	18″	89	75·0	530
6.25	541	133	408	1390	350	388	25·9	125	16·4	294	0·28	0·20	0·02	24″ at 6·10	90	75·0	600
6.40	537	129	408	1390	330	428	......	125	16·4	294	0·30	0·20	0·02	24″	89	75·0	710
					Total	17,691·5											
						Mean.	....	120·4	15·6	292·3	–0·28	–0·18	–0·02	....	91·5	74·0	616
						Corr.	....	118·4	15·6	292·3	....	....	....	....	90·5	73·5	616